Attachment 8D

Estuary Channel Evaluations

CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

2012 Central Valley Flood Protection Plan

Attachment 8D: Estuary Channel Evaluations

June 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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1.0 Introduction

This section states the purpose of this attachment, gives background information (including a description of planning areas, goals, and approaches), introduces the Sacramento-San Joaquin Delta (Delta) region, and provides an overview of the report organization.

1.1 Purpose of this Attachment

As part of development of the 2012 Central Valley Flood Protection Plan (CVFPP), hydraulic modeling was performed for the Sacramento River Basin, San Joaquin River Basin, Stockton area, and Delta region to support flood management system evaluations. Results from the hydraulic modeling were used to describe the hydraulic performance of the existing flood management system (No Project) and to simulate management actions for various approaches to improving the system. Hydraulic modeling results were also used as input to flood damage evaluation models to estimate economic values of flood damages (Attachment 8F: Flood Damage Analysis).

This attachment documents estuary hydraulic modeling methodology and results for the Delta for each of the following CVFPP approaches:

- No Project
- Achieve State Plan of Flood Control (SPFC) Design Flow Capacity
- Protect High Risk Communities
- Enhance Flood System Capacity
- State Systemwide Investment

Riverine channel hydraulic modeling of the Sacramento and San Joaquin river basins using UNET models (documented in Attachment 8C: Riverine Channel Evaluations) provided the upstream boundary conditions for the Resource Management Associates, Inc. (RMA) Delta Model used to simulate estuary channel hydraulics in the Delta.

This attachment documents the following modeling results:

- Stage-frequency (S-F) relationship for in-river locations inside estuarine channels of the Delta. Frequency for storm events of various annual exceedence probabilities (AEP) is expressed in percentage (i.e., 1 percent AEP, or a storm with a 100-year return period).

- Out-of-system volume from river reaches in the Delta. This represents the total volume of water that would leave Delta channels and enter into an island through levee breaches due to levee overtopping. Out-of-system volume is in thousand acre-feet (TAF).

After completion of the 2012 CVFPP, new riverine and floodplain models developed by the Central Valley Floodplain Evaluation and Delineation Program (CVFED) will be become available for use in the 2017 CVFPP.

1.2 Background

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, the California Department of Water Resources (DWR) has prepared a sustainable, integrated flood management plan called the CVFPP, for adoption by the Central Valley Flood Protection Board (Board). The 2012 CVFPP provides a systemwide approach to protecting lands currently protected from flooding by existing facilities of the SPFC, and will be updated every 5 years.

As part of development of the CVFPP, a series of technical analyses were conducted to evaluate hydrologic, hydraulic, geotechnical, economic, ecosystem, and related conditions within the flood management system and to support formulation of system improvements. These analyses were conducted in the Sacramento River Basin, San Joaquin River Basin, and Delta.

1.3 CVFPP Planning Areas

For planning and analysis purposes, and consistent with legislative direction, two geographical planning areas were important for CVFPP development (Figure 1-1):

- **SPFC Planning Area –** This area is defined by the lands currently receiving flood protection from facilities of the SPFC (see *State Plan of Flood Control Descriptive Document* (DWR, 2010a)). The State of California's (State) flood management responsibility is limited to this area.

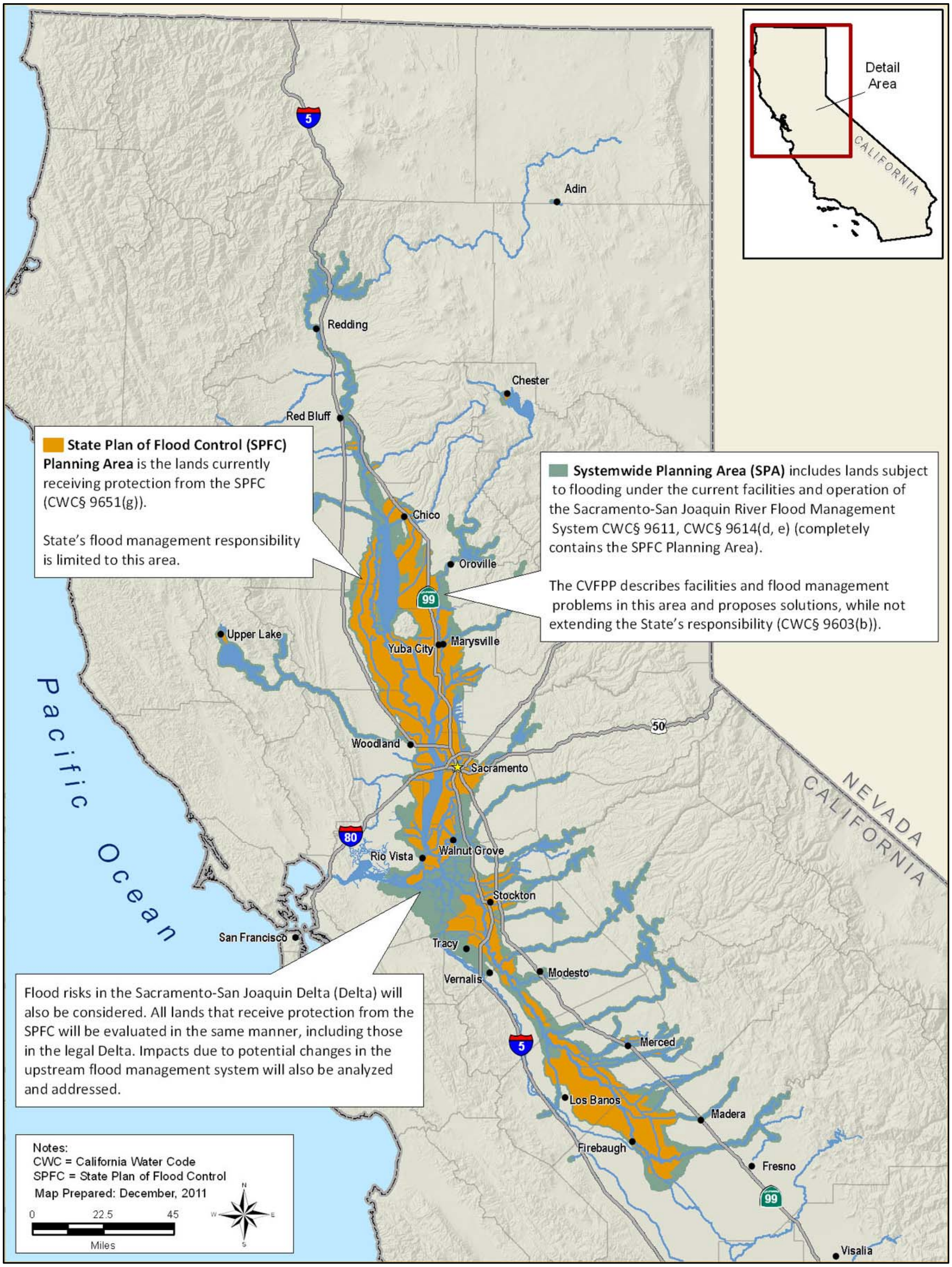

Figure 1-1. Central Valley Flood Protection Plan Planning Areas

- **Systemwide Planning Area –** This area includes the lands that are subject to flooding under the current facilities and operation of the Sacramento-San Joaquin River Flood Management System (California Water Code Section 9611). The SPFC Planning Area is completely contained within the Systemwide Planning Area which includes the Sacramento River Basin, San Joaquin River Basin, and Delta regions.

Planning and development for the CVFPP occurs differently in these planning areas. The CVFPP focused on SPFC facilities; therefore, evaluations and analyses were conducted at a greater level of detail within the SPFC Planning Area than in the Systemwide Planning Area.

Hydraulic modeling was performed for the SPFC Planning Area and Delta. This attachment focuses on the Delta. Hydraulic modeling of the Sacramento and San Joaquin river basins and the Stockton area was conducted separately and is described in Attachment 8C: Riverine Channel Evaluations. Riverine hydraulic modeling results from the Sacramento and San Joaquin river basins provided the upstream boundary conditions (inputs) for the Delta hydraulic modeling described in this attachment.

1.4 2012 CVFPP Planning Goals

To help direct CVFPP development to meet legislative requirements and address identified flood-management-related problems and opportunities, a primary and four supporting goals were developed:

- **Primary Goal –** Improve Flood Risk Management
- **Supporting Goals**:
  - Improve Operations and Maintenance
  - Promote Ecosystem Functions
  - Improve Institutional Support
  - Promote Multi-Benefit Projects

Modeling results in this attachment demonstrate how each of the approaches (described below) meets the primary goal.

1.5 2012 CVFPP Planning Approaches

In addition to **No Project**, three fundamentally different approaches to flood management were initially compared to explore potential improvements in the Central Valley. These approaches are not alternatives; rather, they bracket a range of potential actions and help explore trade-offs in costs, benefits, and other factors important in decision making. The approaches are as follows:

- **Achieve SPFC Design Flow Capacity –** Address capacity inadequacies and other adverse conditions associated with existing SPFC facilities, without making major changes to the footprint or operation of those facilities.

- **Protect High Risk Communities –** Focus on protecting life safety for populations at highest risk, including urban areas and small communities.

- **Enhance Flood System Capacity –** Seek various opportunities to achieve multiple benefits through enhancing flood system storage and conveyance capacity.

Comparing these approaches helped identify the advantages and disadvantages of different combinations of management actions, and demonstrated opportunities to address the CVFPP goals to different degrees.

Based on this evaluation, a **State Systemwide Investment Approach** was developed that encompasses aspects of each of the approaches to balance achievement of the goals from a systemwide perspective, and includes integrated conservation elements. Figure 1-2 illustrates this plan formulation process.

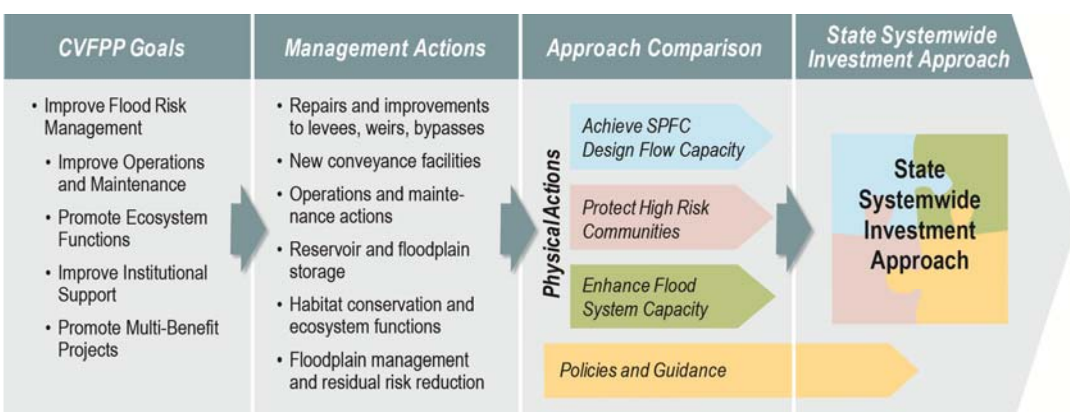

Figure 1-2. Formulation Process for State Systemwide Investment Approach

1.6 Delta Region

The Delta is the West Coast's largest estuary, encompassing approximately 1,153 square miles of waterways through which passes more than 40 percent of the freshwater in California. Sixteen of California's major rivers provide flow to the Delta as tributaries of the Sacramento River, California's largest river, or of the San Joaquin River. The Sacramento and San Joaquin rivers flow from low-lying inland valleys into the Delta – a labyrinth of islands, sloughs, canals, and channels – continuing through Grizzly Bay, Suisun Bay, and San Pablo Bay, before emptying into San Francisco Bay and then finally the Pacific Ocean. The Cosumnes, Mokelumne, and Calaveras rivers, Yolo Bypass, and numerous smaller creeks and sloughs enter the Delta in addition to the Sacramento and San Joaquin rivers. The largest source of water for the Delta is the Sacramento River, which transports about 18.3 million acre-feet (MAF) into the Delta in an average year. Additional flows from the Yolo Bypass and the San Joaquin River contribute an average of 5.8 MAF, with precipitation adding about another 1 MAF.

Freshwater from the rivers mixes with saltwater from ocean tides, creating a rich and diverse estuarine ecosystem. Because of its geographical location, the Delta serves as the collection point for much of Northern California's runoff and resulting water supplies. It is through the channels of the Delta that this water must pass to satisfy the water supply needs of the Delta, San Francisco Bay Area (Bay Area), agricultural lands of the San Joaquin River Basin, and densely populated southlands.

The flood management system in the Delta manages flows from the Sacramento and San Joaquin river basins, tributaries, and tides from San Francisco and San Pablo bays. Water management facilities in the Delta include levees around most of the islands, pumping plants, control gates, port facilities, gages used in flood and water quality forecasting, and diversion and inlet structures.

1.7 Report Organization

Organization of this document is as follows:

- Section 1 describes the purpose of this attachment, and provides an overview of the CVFPP and the Sacramento and San Joaquin river basins.

- Section 2 summarizes results and findings for CVFPP estuary hydraulic modeling.

- Section 3 describes overall CVFPP hydraulic modeling methodology, estuary model selection, and RMA Delta Model specifications.
- Section 4 provides complete results for the estuary hydraulic analysis by CVFPP approach.
- Section 5 contains references for the sources cited in this document.
- Section 6 lists abbreviations and acronyms used in this document.

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2.0 Results Summary and Findings

Results from hydraulic modeling of the Delta are summarized in Figures 2-1 through 2-12, which map the changes in stage between the No Project condition and the four CVFPP approaches throughout the system.

Maps are only included for AEPs of 2 percent, 1 percent, and 0.5 percent (50-, 100-, and 200-year return period) because the flood management system doesn't exhibit significant differences between the No Project and the four approaches for the 10 percent and 4 percent (10- and 25-year return period), and similarly the 0.2 percent AEP flood (500-year return period) overwhelms the flood management system in all cases.

2.1 Achieve SPFC Design Flow Capacity Approach

Figures 2-1 through 2-3 indicate the changes in Delta stages that would result from repairing or improving all SPFC levees to meet their design flows (Section 3.5, Tables 3-1 and 3-2) as specified by the 55/57 design profiles. Overall, for all of the AEPs there would be fewer upstream levee breaks, resulting in increased flows and higher water surface elevations in the Delta, particularly in the areas where the Sacramento and San Joaquin rivers enter the Delta.

2.2 Protect High Risk Communities Approach

Figures 2-4 through 2-6 indicate the changes in stage that would result from repairing or improving all urban levees to meet the 0.5 percent AEP (200-year) design criteria (Section 3.6, Tables 3-1 and 3-2), and providing increased protection to selected small communities. Since this approach would improve only urban and small community levees, other levees would be untouched and function as in the No Project condition. Stage increases of a foot or less would be seen on the Delta as a result of increased protection for upstream urban areas.

2.3 Enhance Flood System Capacity Approach

Figures 2-7 through 2-9 indicate the changes in stage that would result from modifying the flood management system as described in Section 3.7 and shown in Tables 3-1 and 3-2. Key components of the approach are added upstream reservoir storage, improving SPFC levees to their design flow capacity, improving urban levees to pass the 0.5 AEP flood, widened and new bypasses, levee setbacks, and floodplain storage. The added upstream and floodplain storage in the Sacramento River Basin would result in lower stages entering and in the interior of the Delta for all AEPs. The Paradise Cut Bypass enlargement and Roberts Island floodplain storage lower stages on the San Joaquin River from Paradise Cut to Stockton.

2.4 State Systemwide Investment Approach

Figures 2-10 through 2-12 indicate the changes in stage resulting from repairing or improving all urban levees to meet the 0.5 percent AEP (200-year) design criteria and other improvements in the State Systemwide Investment Approach (Section 3.8, Tables 3-1 and 3-2). Because this approach would improve only urban levees, other levees would be untouched and function the same as the No Project condition. Stages in the Delta as a result of this approach would be the same as or lower than the No Project condition.

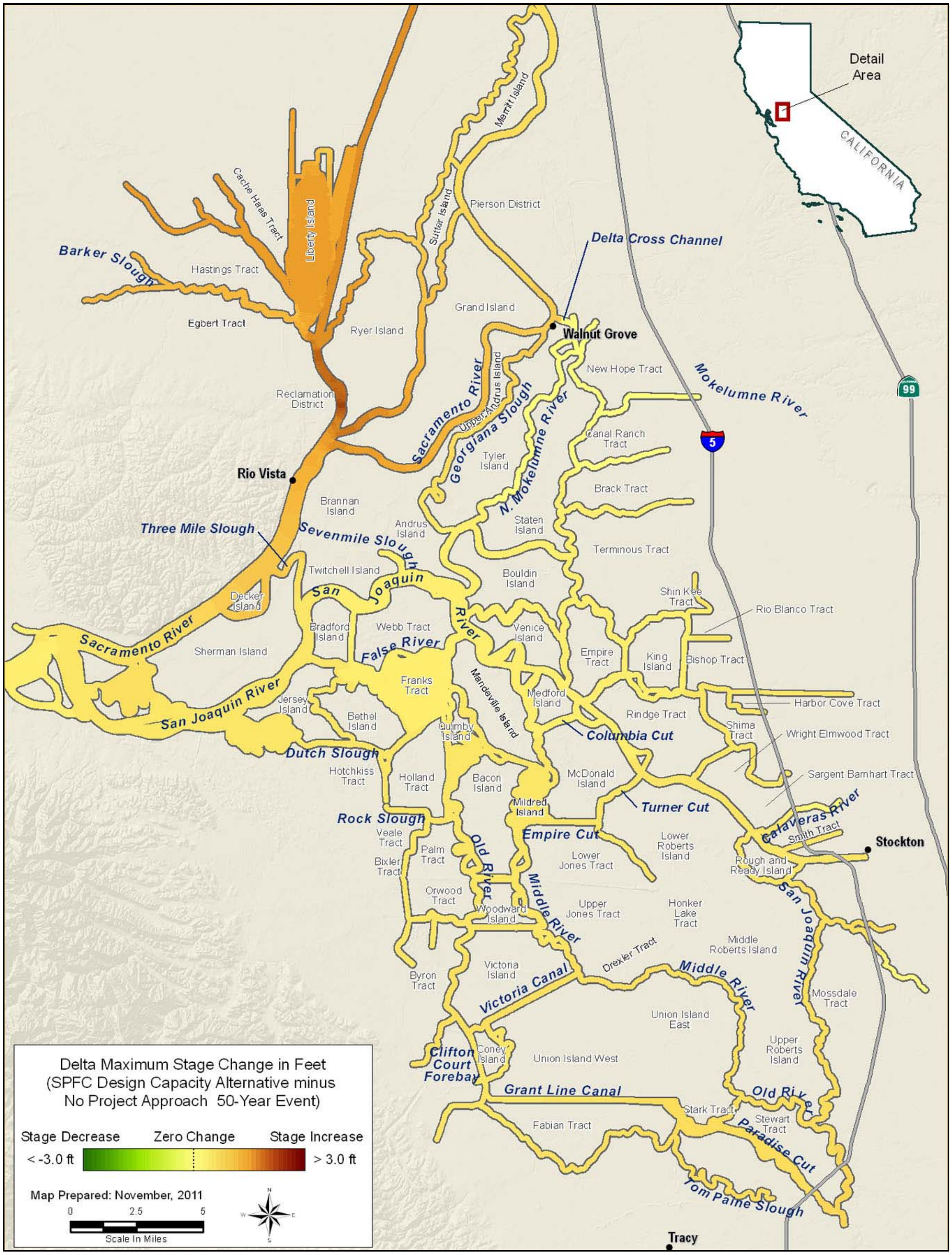


Figure 2-1. Stage Changes from No Project Condition to Achieve SPFC Design Flow Capacity Approach – 2 Percent AEP (50-year)

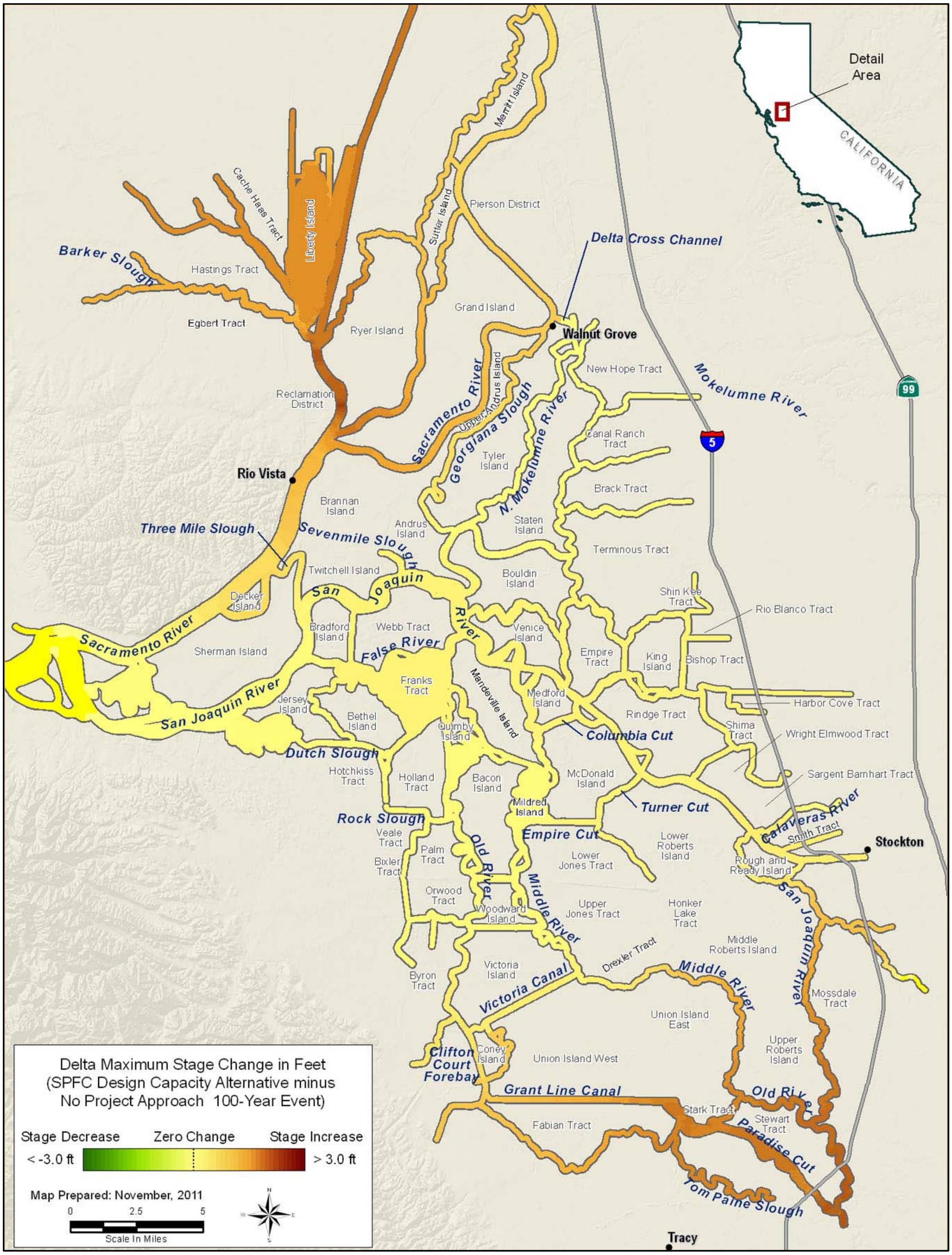


Figure 2-2. Stage Changes from No Project Condition to Achieve SPFC Design Flow Capacity Approach – 1 Percent AEP (100-year)

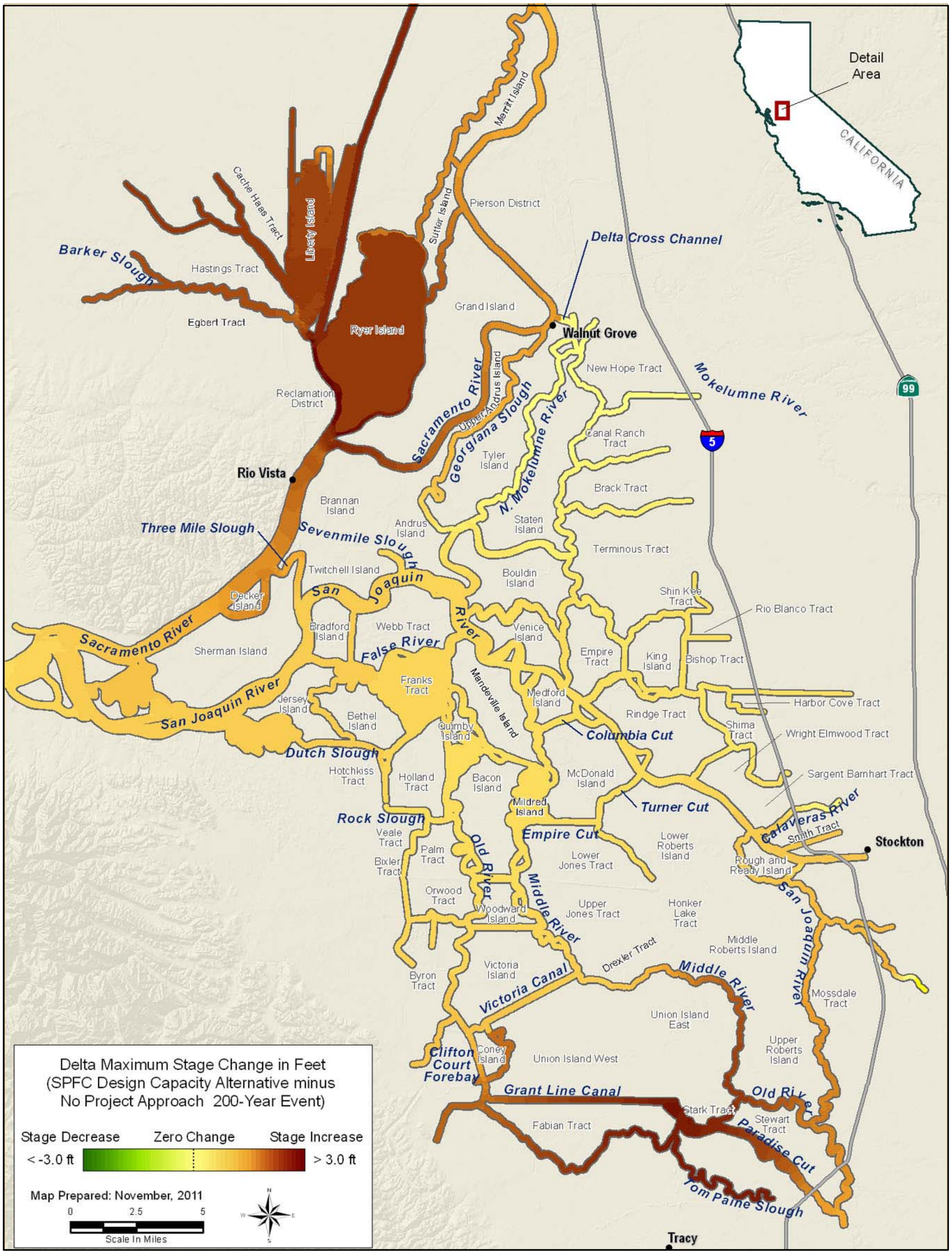


Figure 2-3. Stage Changes from No Project Condition to Achieve SPFC Design Flow Capacity Approach – 0.5 Percent AEP (200-year)

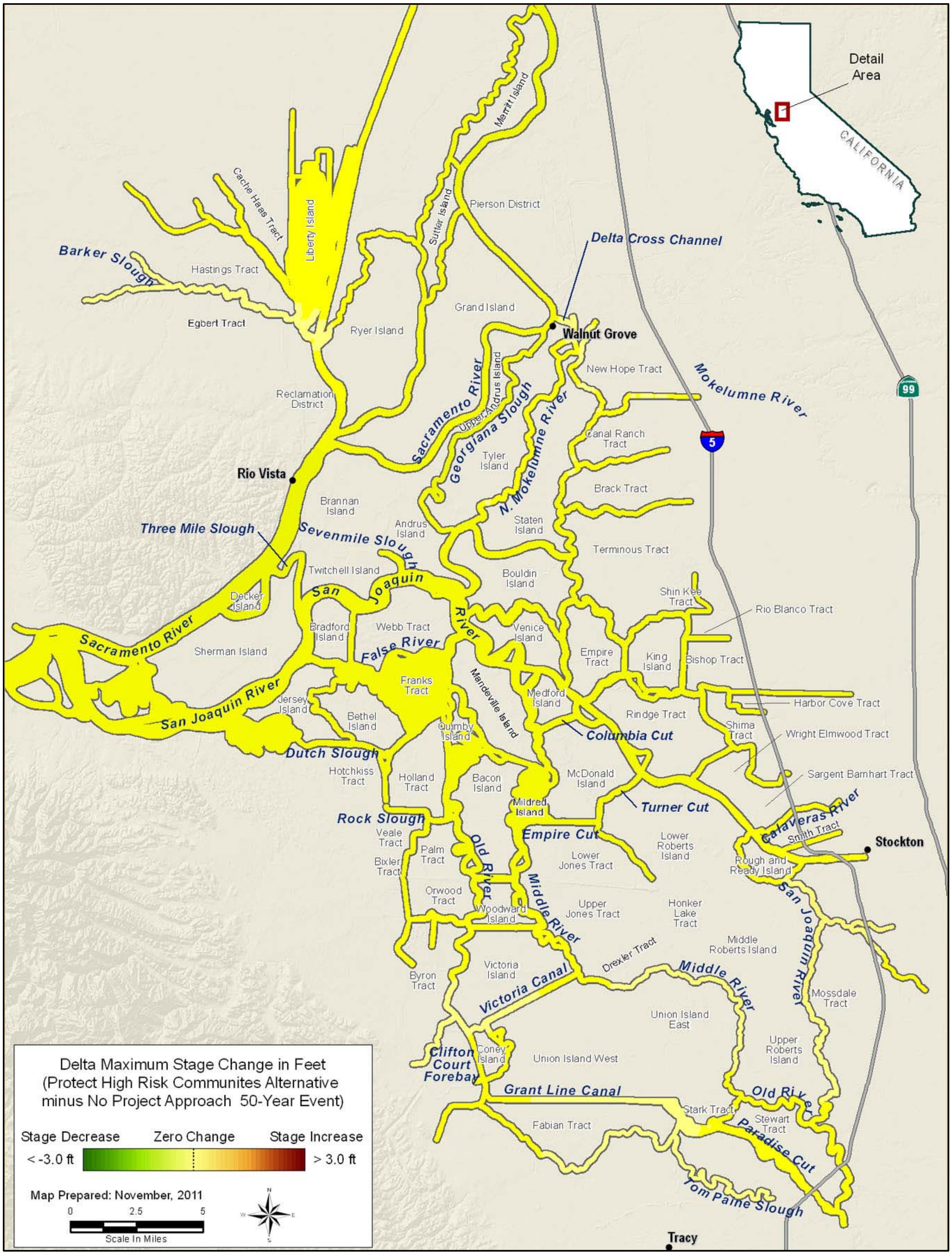


Figure 2-4. Stage Changes from No Project Condition to Protect High Risk Communities Approach – 2 Percent AEP (50-year)

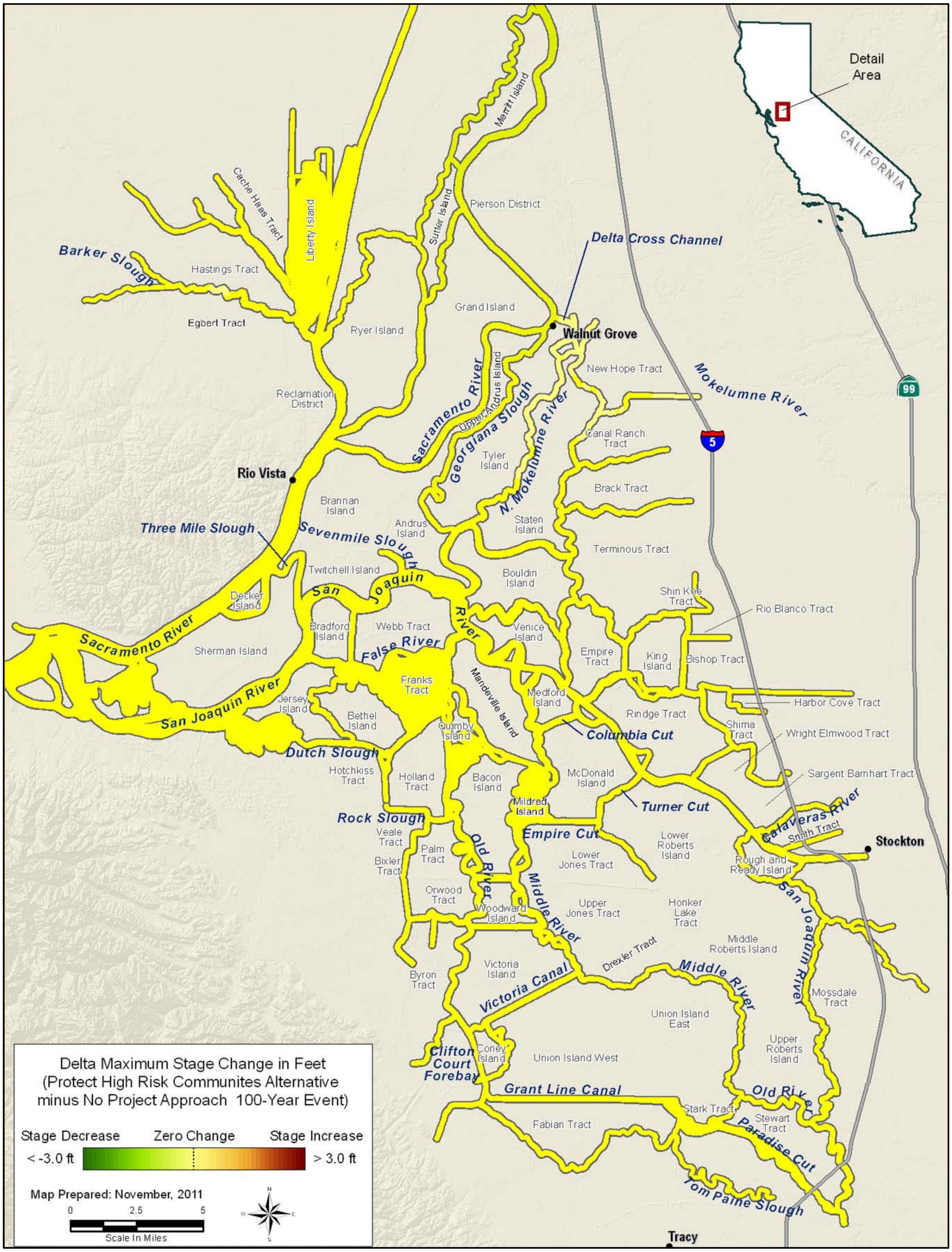


Figure 2-5. Stage Changes from No Project Condition to Protect High Risk Communities Approach – 1 Percent AEP (100-year)

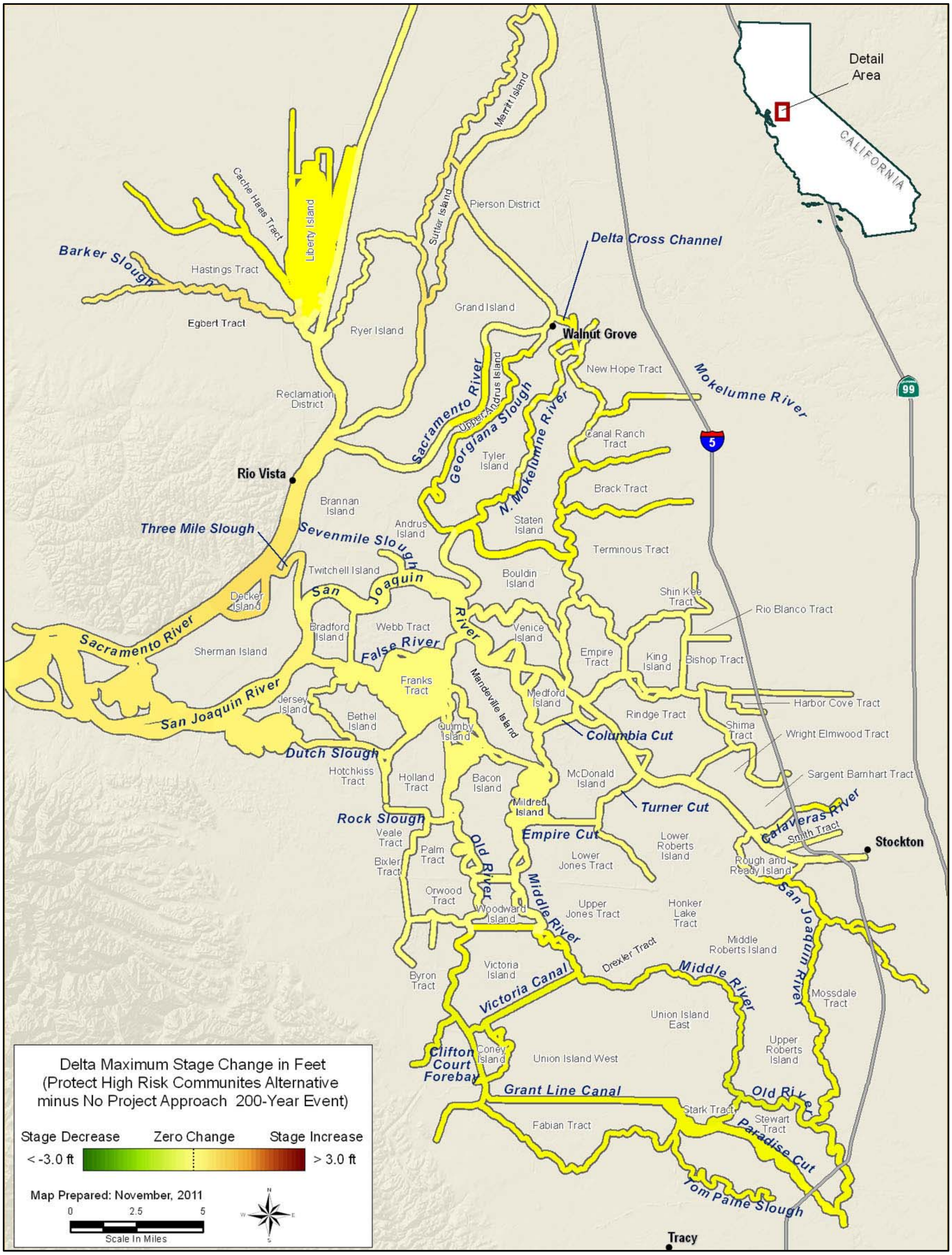


Figure 2-6. Stage Changes from No Project Condition to Protect High Risk Communities Approach – 0.5 Percent AEP (200-year)

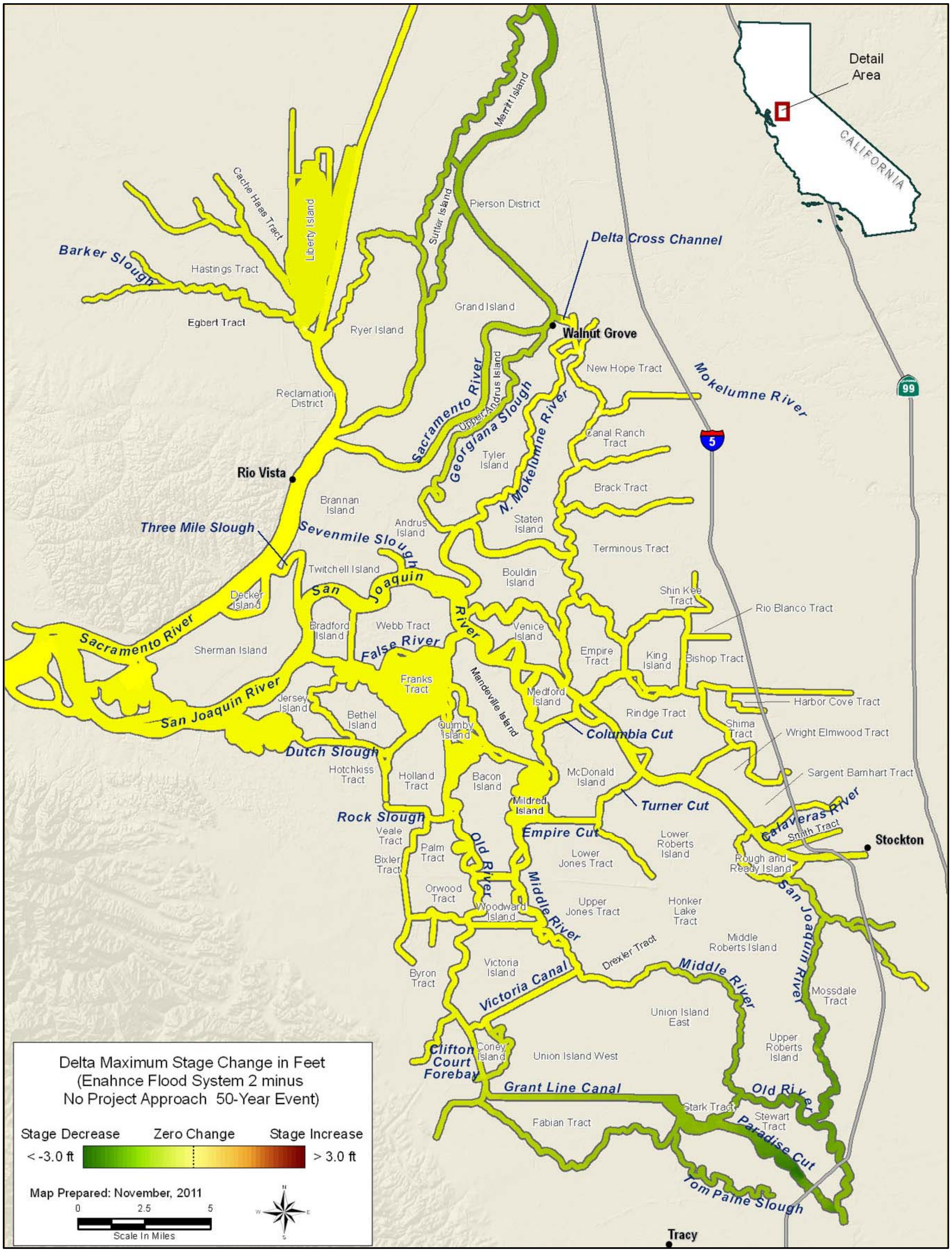


Figure 2-7. Stage Changes from No Project Condition to Enhance Flood System Capacity Approach – 2 Percent AEP (50-year)

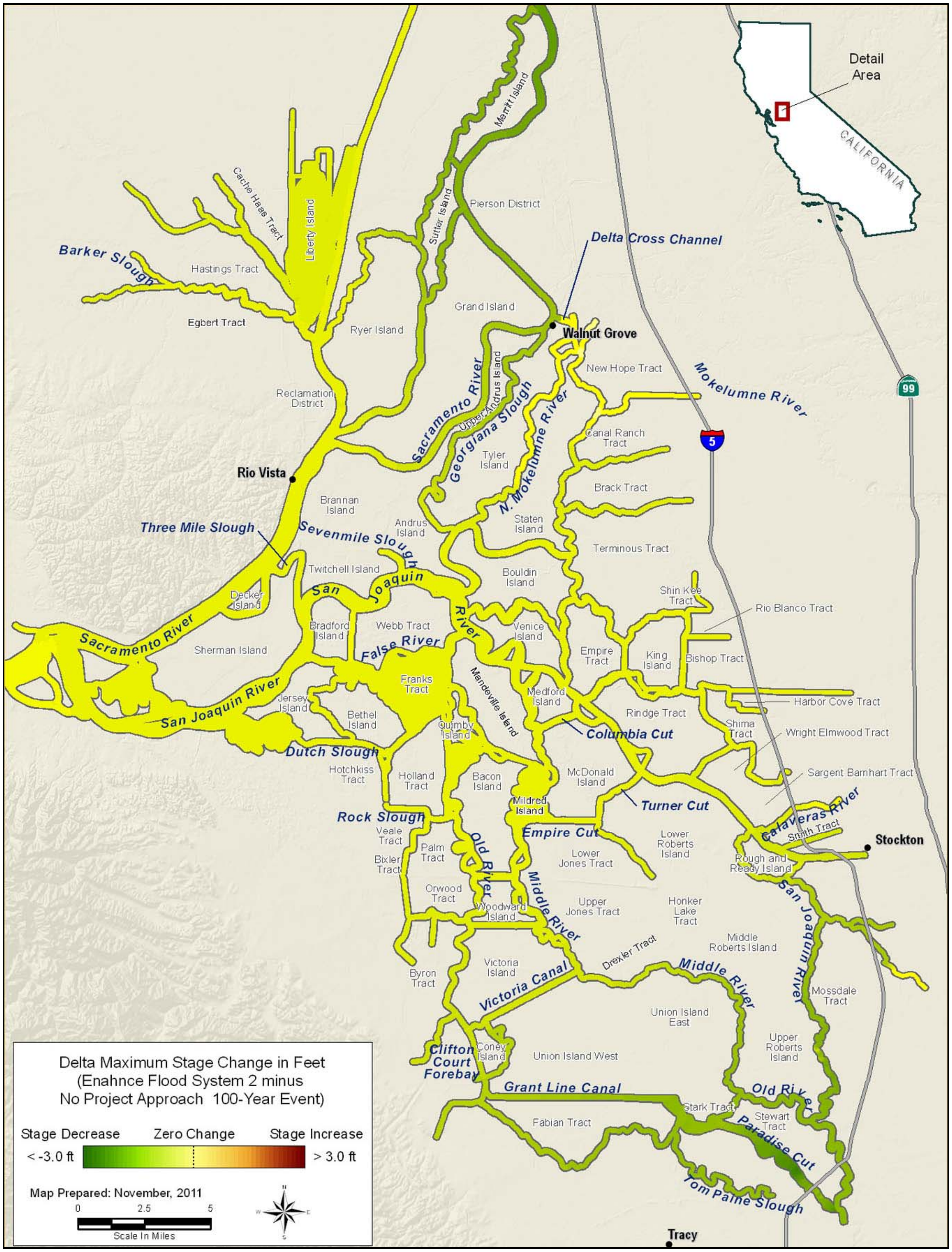


Figure 2-8. Stage Changes from No Project Condition to Enhance Flood System Capacity Approach – 1 Percent AEP (100-year)

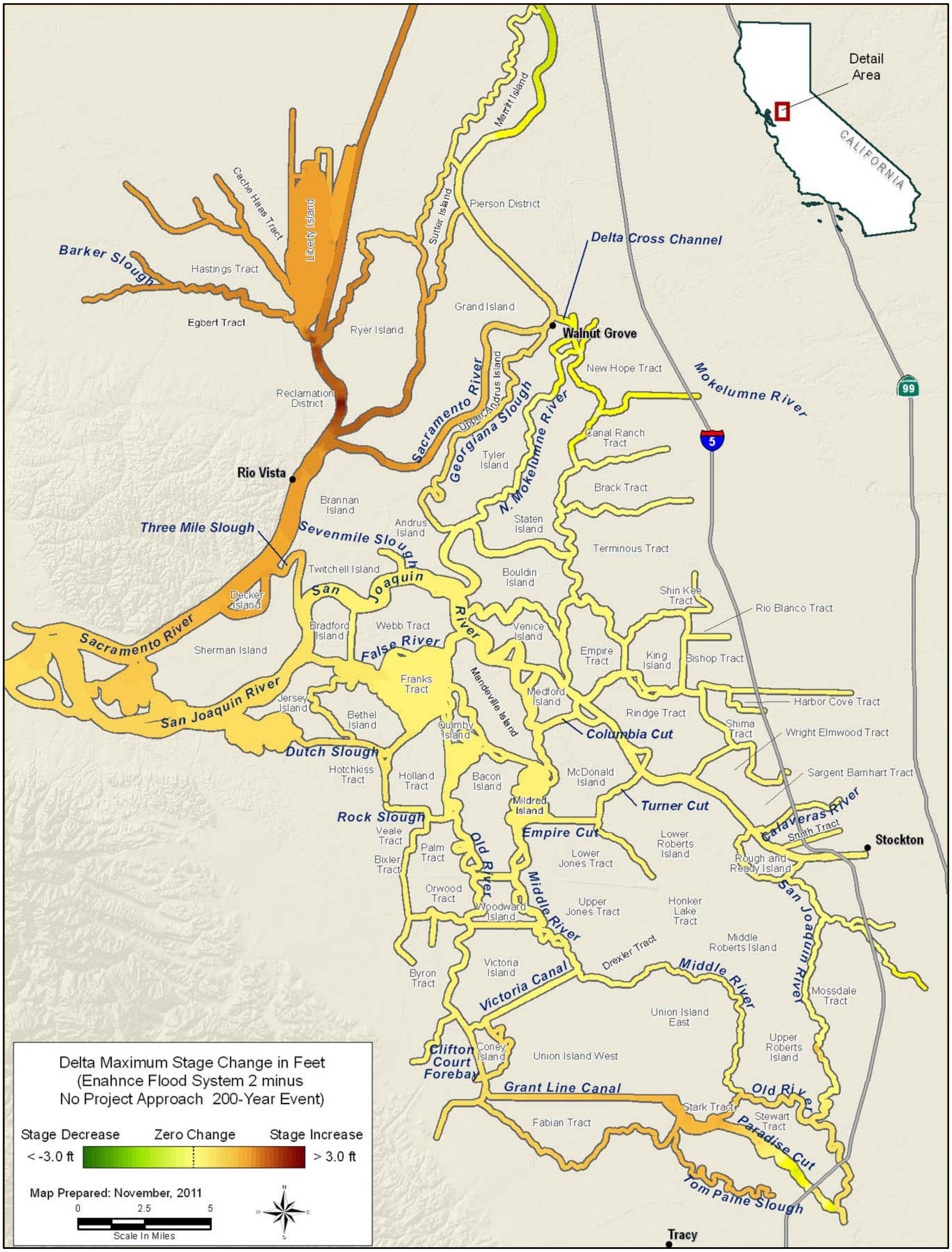


Figure 2-9. Stage Changes from No Project Condition to Enhance Flood System Capacity Approach – 0.5 Percent AEP (200-year)

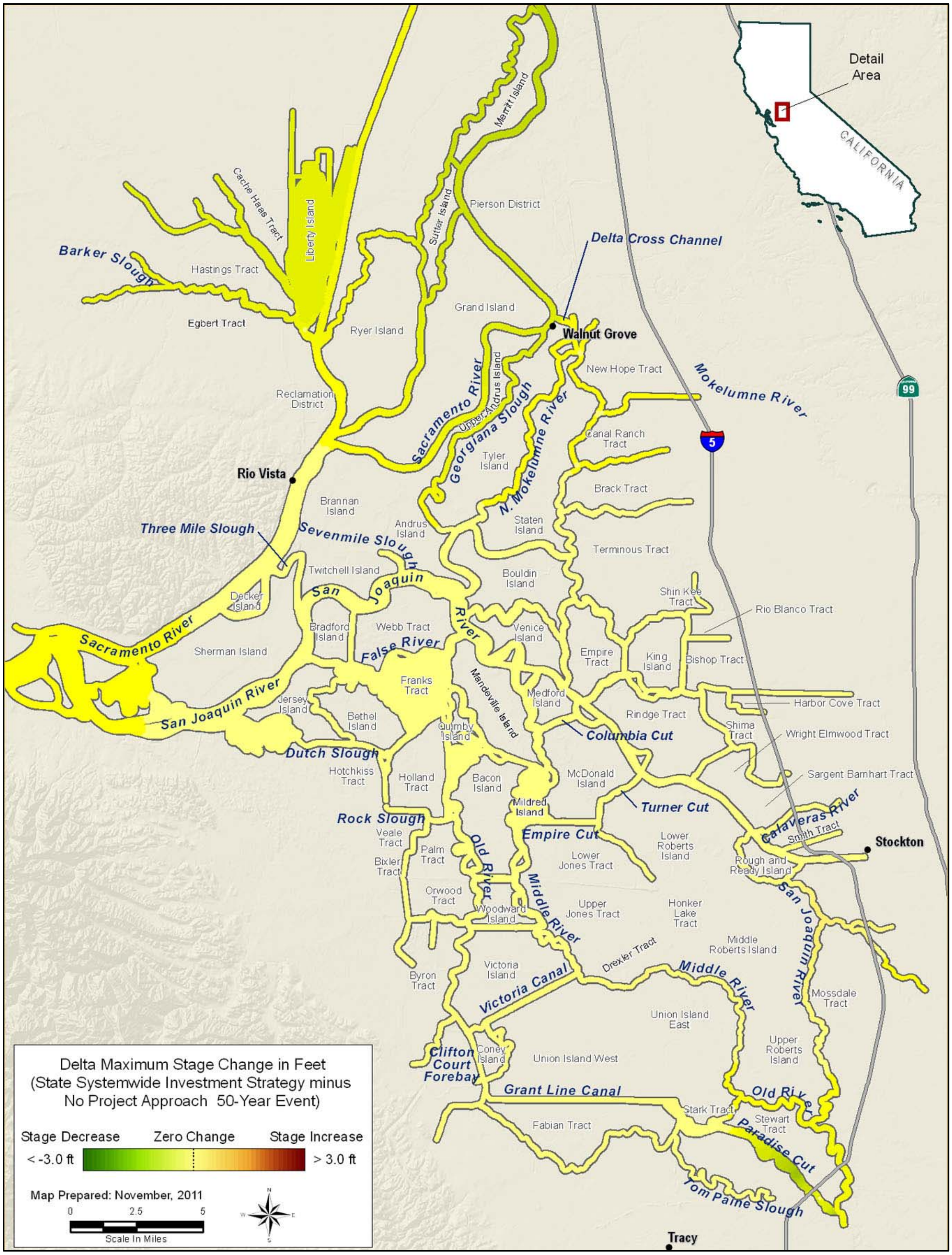


Figure 2-10. Stage Changes from No Project Condition to State Systemwide Investment Approach – 2 Percent AEP (50-year)

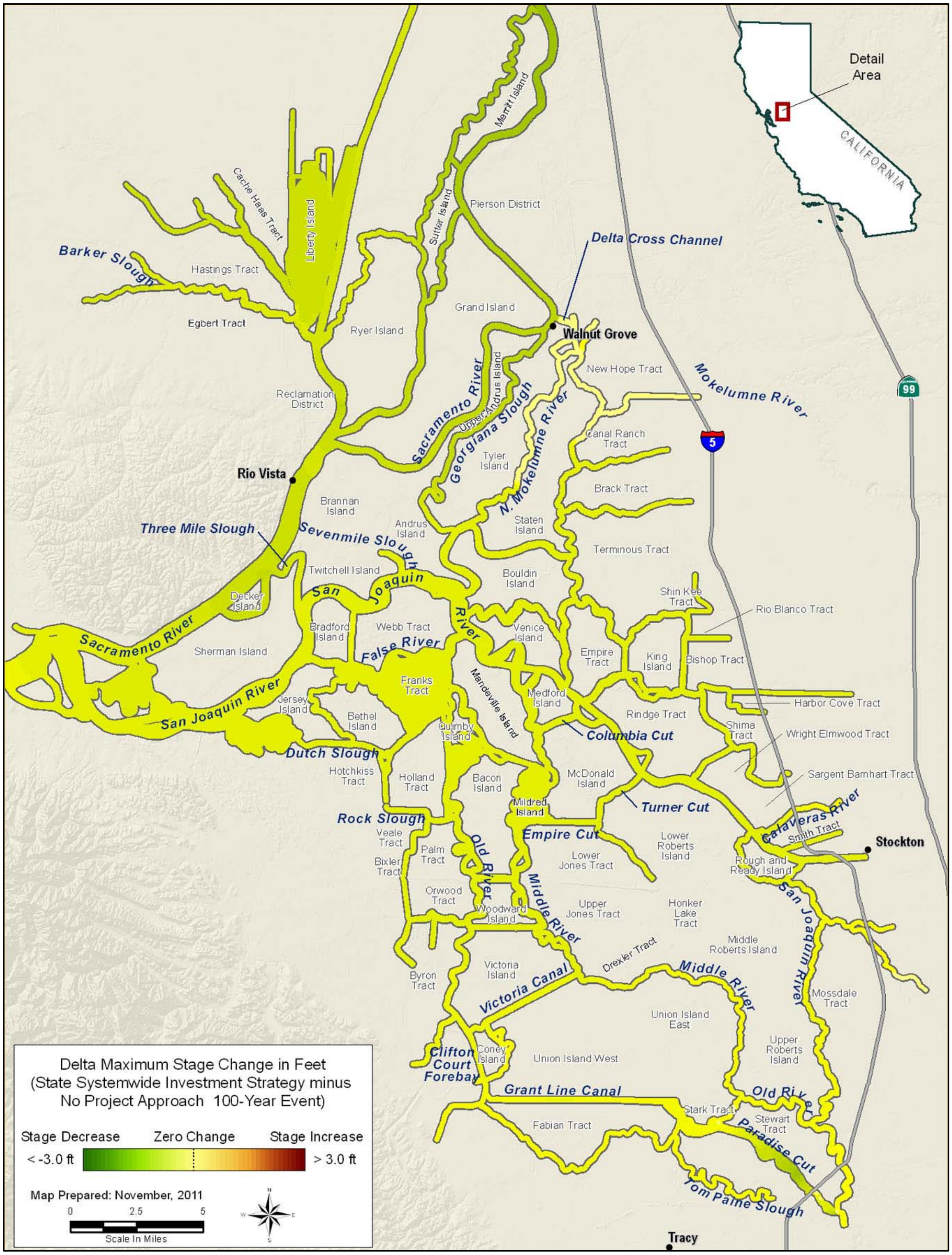


Figure 2-11. Stage Changes from No Project Condition to State Systemwide Investment Approach – 1 Percent AEP (100-year)

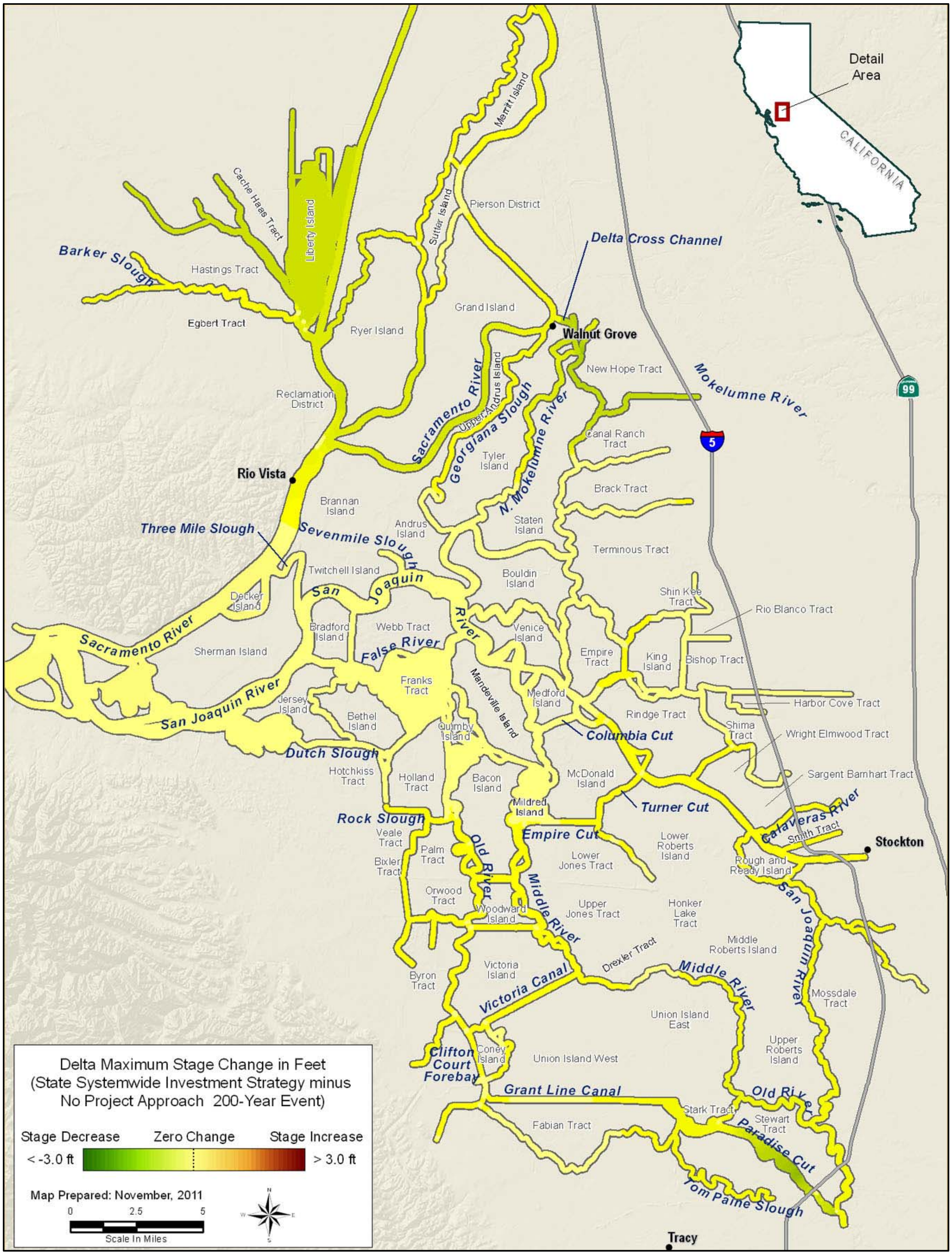


Figure 2-12. Stage Changes from No Project Condition to State Systemwide Investment Approach – 0.5 Percent AEP (200-year)

3.0 Methodology

This section provides an overview of the CVFPP modeling framework, model selection, the RMA Delta Model, and modeling assumptions for the No Project condition and each CVFPP approach.

It is important to note that the hydraulic modeling conducted using the RMA Delta Model is a deterministic process that simulates levee breaches based on data provided regarding levee performance. Hydraulic modeling cannot and does not predict the location of actual levee breaches.

3.1 CVFPP Modeling Overview

Figure 3-1 shows the overall hydraulic modeling schematic for the CVFPP. With defined boundary conditions (including upstream hydrographs to represent storm events, downstream tailwater stage, levee breach scenarios, etc.), riverine hydraulic conditions were simulated to generate hydrographs that would be the upstream boundary conditions for the Delta hydraulic model. The Delta hydraulic model was then used to estimate the water stage for locations inside the Delta. Details of the riverine hydraulic modeling are contained in Attachment 8C: Riverine Channel Evaluations. All flows from areas protected by the SPFC eventually pass through the Delta; therefore, estuary hydraulic modeling using existing tools was an important part of the hydraulic analyses needed to support the CVFPP development.

3.2 Model Selection

Two existing hydraulic models were evaluated for use in determining water stages in the Delta: the Delta Simulation Model II (DSM2) and the RMA Delta Model.

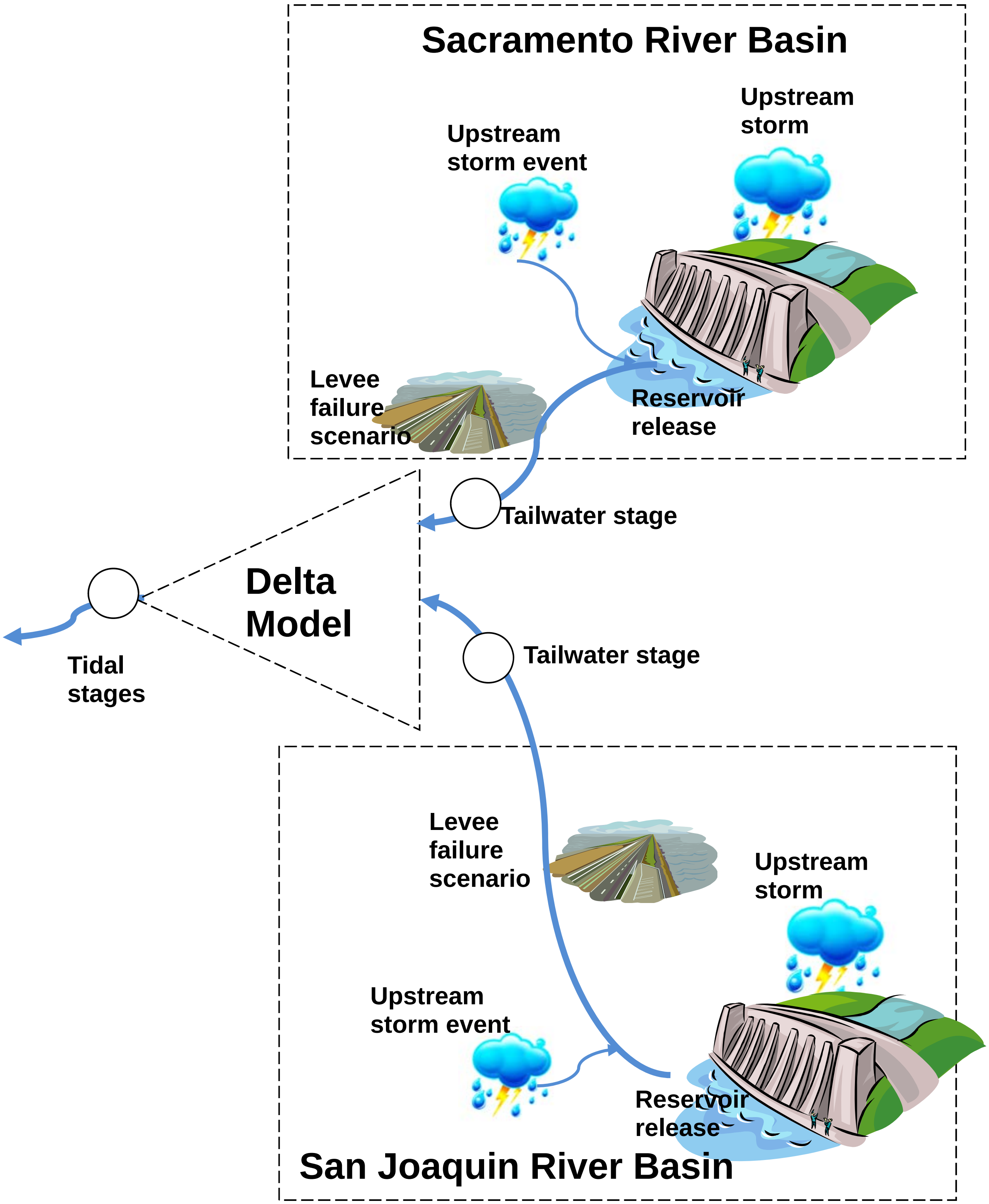


Figure 3-1. Schematic of CVFPP Hydraulic Modeling

DSM2, developed by DWR in the early 1990s, is a branched one-dimensional (1-D), physically based numerical model of the Delta. DSM2-Hydro, the hydrodynamics module, is derived from the U.S. Geological Survey (USGS) Four Point Model. Key DSM2 inputs for the hydrodynamic module include tidal stage at Martinez, boundary inflows (e.g., Sacramento and San Joaquin rivers, Yolo Bypass, eastside streams), and operations of flow-control structures (e.g., Clifton Court Forebay gates, Delta Cross Channels). DSM2 uses the Delta Island Consumptive Use (DICU) Model to develop agricultural diversions and return flow to each of 142 Delta subareas. The DICU follows the seasonal pattern of irrigation diversions during the summer and drainage return flows from winter runoff.

The RMA Delta Model uses finite element analysis to enable a mixed representation of two-dimensional (2-D) depth-averaged elements and 1-D channel elements. For systems such as the San Francisco Bay-Delta, the 2-D depth-averaged elements are typically used to represent the open waters of the bays and large river channels while the 1-D elements are used for reproducing flow and transport for simple channels in the Delta (RMA, 2005). Boundary conditions and model extents for the RMA Delta Model are similar to DSM2. The RMA Delta Model also uses DICU Model outputs for agricultural diversions and return flows into the Delta.

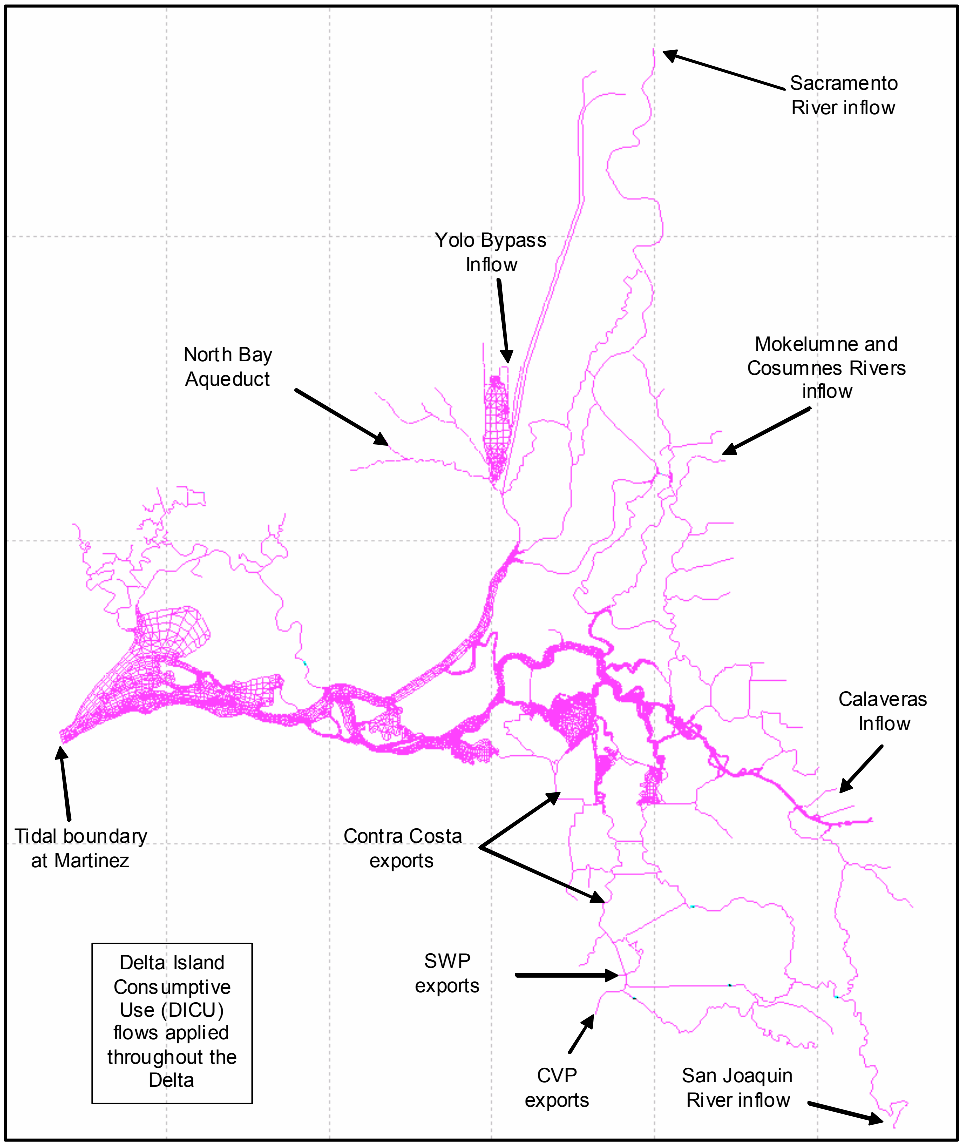
The RMA Delta Model can explicitly simulate levee breaches and inundation of islands to estimate interior flood depth using available elevation data for levee crest and Delta island topography. Therefore, the RMA Delta Model was selected for this CVFPP estuary channel evaluation to estimate Delta in-channel water stage and flooding inside islands.

3.3 RMA Delta Model Overview

The RMA Delta Model is a calibrated finite element model for surface water hydrodynamics simulation to compute 2-D depth-averaged velocity and water surface elevation. This model encompasses the major rivers and channels of the Delta system. Figure 3-2 shows a schematic of the RMA Delta Model (RMA, 2005).

The RMA Delta Model employs 2-D depth-averaged elements to represent large open water areas of the system, such as the area in and around Franks Tract, the Sacramento-San Joaquin River confluence, and Suisun Bay. For this CVFPP estuary channel evaluation, the 2-D depth-averaged elements were extended on the Sacramento River near Rio Vista, and on the San Joaquin River to the Port of Stockton.

Other channels of the Delta are represented by 1-D channel elements for simplified representations of channel cross sections in trapezoidal shape. The 1-D elements have a provision for off-channel storage or an ineffective flow area. This feature is typically used to represent shallow water or marsh areas bordering the main flow channel. Off-channel storage is also defined with a simplified geometry.



Source: RMA, 2005

Figure 3-2. Schematic of RMA Delta Model

By default, the outer boundary or shoreline encompassing the 2-D network elements are treated as “infinite walls” where no overtopping flow is allowed. This is also true for flow in the 1-D channel elements. Top of levee (TOL) elevations can be changed with time on a node-by-node basis to allow complete simulation of a breaching event and later levee repair.

3.4 Modeling Assumptions for No Project Condition

Tables 3-1 and 3-2 show modeling assumptions for the Sacramento and San Joaquin river basins, respectively, for the No Project condition and all of the CVFPP approaches. The following sections describe assumptions in the RMA Delta Model for the CVFPP No Project condition.

3.4.1 Paradise Cut Modifications

The Lower San Joaquin River (LSJR) model was developed and calibrated for River Islands at Lathrop using the Hydrologic Engineering Center River Analysis System (HEC-RAS). The model was constructed by converting a portion of the San Joaquin River Comprehensive Study UNET Model to the HEC-RAS platform, with additional refinements in floodplain geometry and hydraulic connections. Figure 3-3 shows the extent of the LSJR HEC-RAS model (MBK, 2006).

Geometry data in the RMA Delta Model were modified to reflect refinements made in the LSJR HEC-RAS Model, as follows:

- The junction of Paradise Cut (see Figure 3-3) and the San Joaquin River were modeled with 2-D features to better simulate weir flow.

- Channel representation for the junction of Grant Line Canal/Old River/Paradise Cut was refined and extended.

Table 3-1. Summary of Sacramento River Basin Modeling Assumptions

Element	Description	No Project (NPRJ)	Achieve SPFC Design Flow Capacity (SPFC)	Protect High Risk Communities (PHRC)	Enhance Flood System Capacity (EFSC)	State Systemwide Investment (SSIA)
Levee Setback	Sacramento River RM 199.5 to 197				√	
	Sacramento River RM 169.5 to 111.25				√	
	Feather River RM 24.5 to 0				√	
Levee Improvement	Restore 1955/1957 design levee: Assume levee breach at top of levee in hydraulic model		√		√	
	Fix urban area levee: Assume levee breach at top of levee in hydraulic model			√	√	√
	TRLIA levee improvement	√	√	√	√	√
	Marysville levee improvement	√	√	√	√	√
	Natomas levee improvement	√	√	√	√	√
Bypass	Widen Yolo Bypass[1]				√	√
	Widen Sacramento Bypass and Gates				√	
	Widen Sutter Bypass				√	√
	Feather to Butte Basin (Biggs) Bypass				√	√
Reservoir Storage and Operations	Folsom Dam Joint Federal Project	√	√	√	√	√
	Lake Oroville: Modify Lake Oroville release schedule				√	
	New Bullards Bar and Lake Oroville: Implement coordinated operation of the Feather-Yuba River Basin				√	
Floodplain Storage	Sutter Butte Basin				√	
	Feather River Basin				√	
	Elkhorn				√	
	Merritt Island				√	

Notes:
55/57 levee design profile was the design standard for the State Plan of Flood Control.
[1] Use off-stream storage to model levee setback.

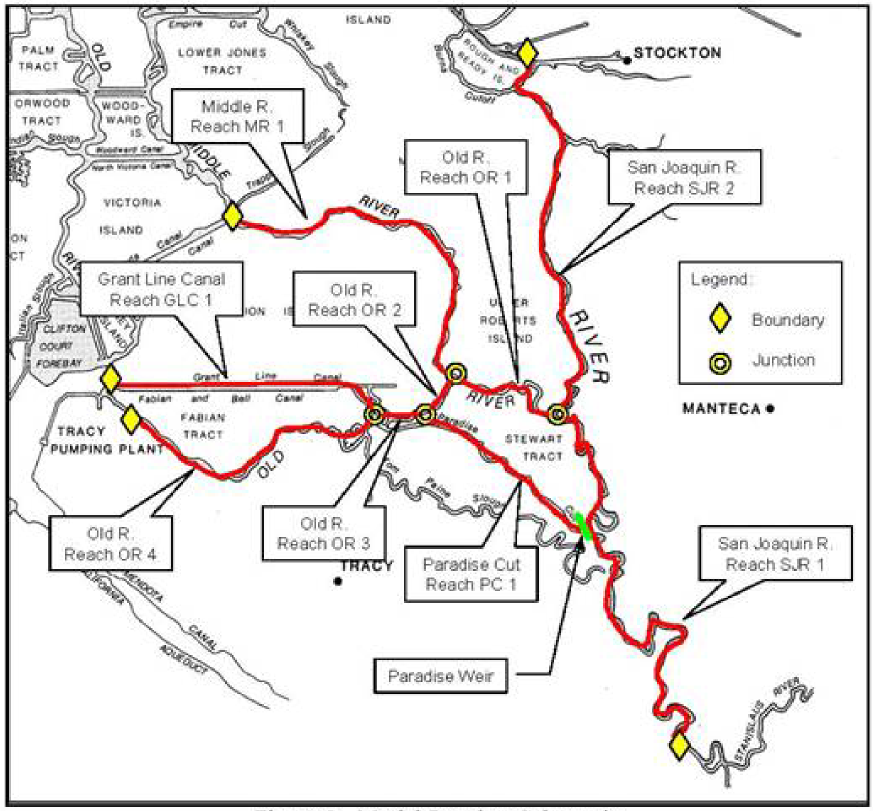
Key:
EFSC = Enhance Flood System Capacity Approach
NPRJ = No project
PHRC = Protect High Risk Communities Approach
RM = River Mile
SPFC = State Plan of Flood Control
SSIA = State Systemwide Investment Approach
TRILIA = Three Rivers Levee Improvement Authority

Table 3-2. Summary of San Joaquin River Basin Modeling Assumptions

Element	Description	No Project (NPRJ)	Achieve SPFC Design Flow Capacity (SPFC)	Protect High Risk Communities (PHRC)	Enhance Flood System Capacity (EFSC)	State Systemwide Investment (SSIA)
Levee Setback	SJR RM115 to 99				√	
	SJR RM 81.5 to 72.5				√	
Levee Improvement	Restore 55/57 levee design profile: Assume levees breach at top of levee in hydraulic model		√		√	
	Fix urban area levees: Assume levees breach at top of levee in hydraulic model			√	√	√
	Restore bypass levees: Assume levees breach at top of levee in hydraulic model		√		√	
Bypass	Widen Paradise Cut				√	√
Reservoir Storage and Operations	New Don Pedro Reservoir: Increase flood storage allocation by 230,000 acre-feet				√	
	Friant Dam and Millerton Lake: Increase flood storage allocation by 60,000 acre-feet				√	
	New Exchequer Dam and Lake: Increase flood storage allocation by 100,000 acre-feet				√	
Floodplain Storage	Roberts Island				√	
	San Joaquin River: between Merced and Tuolumne rivers				√	
	San Joaquin River: between Tuolumne River and Stanislaus River				√	

Note:
55/57 levee design profile was the design standard for the State Plan of Flood Control

Key:
EFSC = Enhance Flood System Capacity Approach
NPRJ = No project
PHRC = Protect High Risk Communities Approach
RM = river mile
SJR = San Joaquin River
SPFC = State Plan of Flood Control
SSIA = State Systemwide Investment Approach
TRLIA = Three Rivers Levee Improvement Authority



(Source: MBK, 2006)

Figure 3-3. Schematic of LSJR HEC-RAS Model for River Islands

3.4.2 Boundary Conditions

UNET model outputs for the Sacramento and San Joaquin river basins for the No Project condition were incorporated into the RMA Delta Model as upstream boundary conditions. These upstream boundary conditions from UNET models were applied into the RMA Delta Model at the following locations (see Figure 3-4):

- Sacramento River downstream from American River confluence
- Yolo Bypass at three locations near Liberty Island
- San Joaquin River at Vernalis[1]

[1] UNET flow for the San Joaquin River upstream from Paradise Cut Weir was applied in the RMA Delta Model at Vernalis (about 13 river miles upstream from the Paradise Cut Weir) by shifting the time-series 10 hours earlier to address the lag time. Also, the RMA Delta Model assumed there was no levee breach along the San Joaquin River between Vernalis and the Paradise Cut Weir. Such a levee breach was addressed in the UNET model.

Flows entering the Delta from eastside streams (collectively referred to as Delta tributaries) were incorporated into the RMA Delta Model based on hydrographs from the Sacramento and San Joaquin River Basins Comprehensive Study (Comprehensive Study)(USACE, 2002a) for six flood events (AEPs of 10, 4, 2, 1, 0.5, and 0.2 percent) to represent flows for: Mokelumne, Cosumnes, and Calaveras rivers, and French Camp Slough (see Figure 3-4).

Historical records from January 1997 were shifted 20 days forward to match the UNET model simulation period (i.e., historical records of January 1 were shifted to January 21 in the RMA Delta Model) and were used as boundary conditions for the following:

- Downstream tidal stage at Martinez
- Central Valley Project (CVP) and State Water Project (SWP) exports
- Operations of control structures in the Delta[2]

[2] Control structures in the Delta of interest include Suisun Marsh Salinity Control gate, Delta Cross Channel, Old River near Tracy barrier, temporary barrier at the head of Old River, Middle River temporary barrier, Clifton Court Forebay Gates, Grant Line Canal barrier, and Rock Slough tide gate.

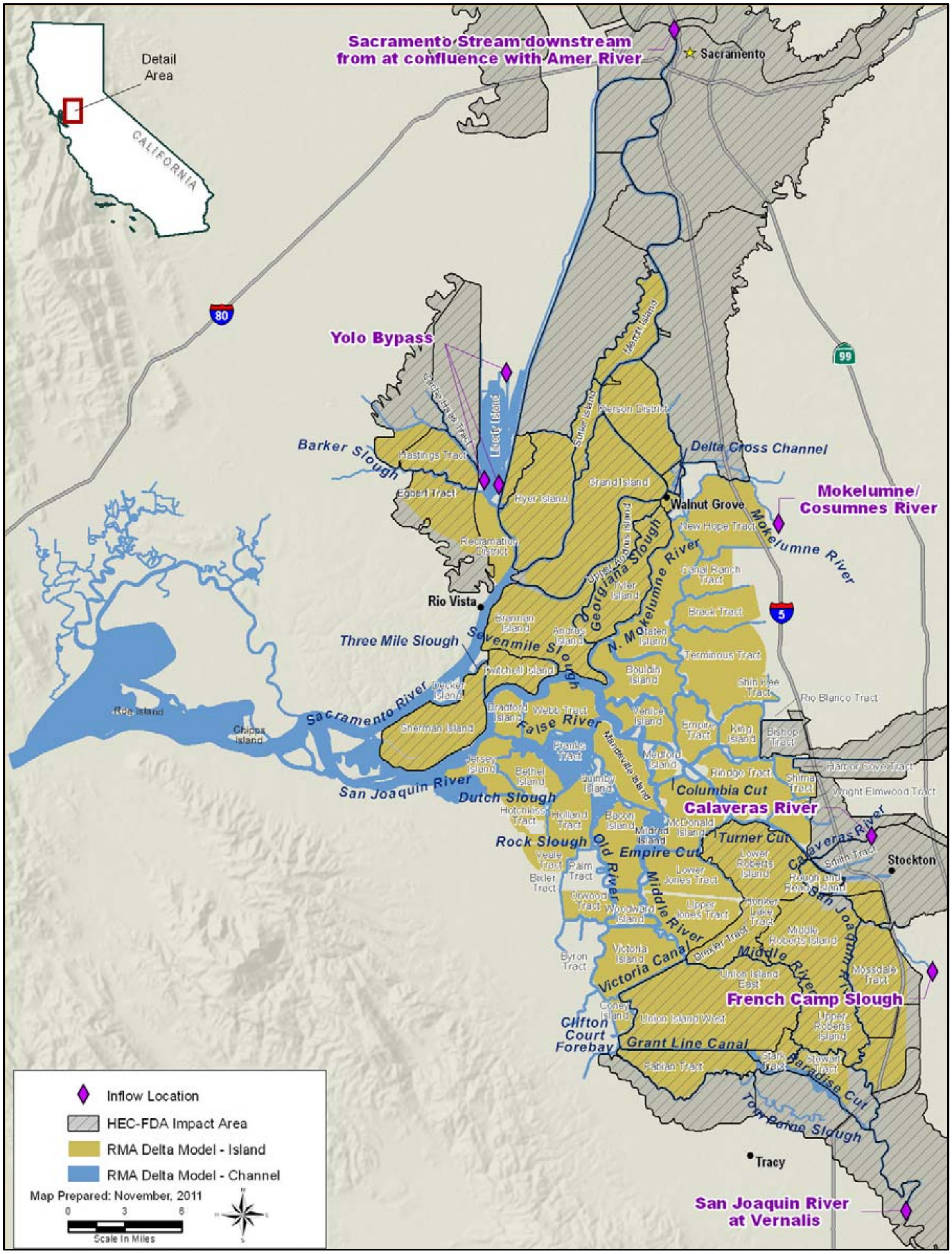


Figure 3-4. Upstream Boundary Inflow Locations for RMA Delta Model

3.4.3 Delta Inflow Annual Exceedence Probabilities

The riverine hydraulic model of the Sacramento River Basin has five storm centerings (Sacramento, Ord Ferry, Shasta, Yuba, and American River) and the San Joaquin River Basin also has five centerings (Vernalis, Newman, El Nido, Merced, and Friant) for six flood events (AEPs of 10, 4, 2, 1, 0.5, and 0.2 percent) (see Attachment 3: Riverine Channel Evaluations).

Only hydrographs from the Sacramento and Vernalis centerings were used as inputs into the RMA Delta Model. These two storm centerings generated the largest peak inflows into the Delta for flood events from the Sacramento and San Joaquin river basins.

The exceedence frequency of storm inflows from the Sacramento and San Joaquin river basins into the Delta from a given storm are not likely to be exactly the same, but inflows from the two basins do have some meteorological connectivity. To help identify a reasonable Sacramento-San Joaquin river inflow coincident probability to use for the Delta channel evaluation, two approaches were taken: review of historical inflows and hydraulic sensitivity analysis.

Historical Flow Review

Historical full natural daily flows from October 1, 1921, through November 18, 1997 (i.e., water years 1922 through 1997), were evaluated at the following locations:

- Sacramento River at latitude Sacramento
- San Joaquin River near Vernalis
- Cosumnes River at Michigan Bar
- Mokelumne River at Camanche Reservoir
- Calaveras River at New Hogan Reservoir

For the historical flow review, a summation of flows from the five sources listed above was used to represent total Delta inflows for each day. An analysis was made of the coincidence of Delta river source inflows with total Delta inflow; results are shown in Figure 3-5. For each water year, the date of maximum Delta total inflow was identified and the recurrence interval was calculated. Flows for the same day on the Sacramento and San Joaquin rivers were identified and the corresponding recurrence interval was then determined for each of those flows and plotted with the total Delta inflow recurrence (see Figure 3-5) to show the correlations.

Figure 3-5 shows that total Delta inflows historically had the highest correlation with Sacramento River flows; a 1 percent AEP event (100-year) in the Delta could be caused by a 1.11 percent AEP event (90-year) on the Sacramento River, which would coincide with a San Joaquin River flood of having an AEP of roughly 1.25 percent (80-year). The differences in coincident AEP are due in part to different timing of peak flows; San Joaquin River flow at Vernalis typically peaked 1 day later than the Sacramento River flow at latitude Sacramento while the Delta tributaries peaked 1 day earlier.

Hydraulic Sensitivity Analysis

A sensitivity analysis was performed using the RMA Delta Model to understand the sensitivity of Delta stages to varying Sacramento and San Joaquin river inflows at the following locations (Figure 3-6):

- Old River near Tracy Temporary Barrier
- Middle River near State Highway 4
- Middle River at Bacon Island
- San Joaquin River at Rindge Pump
- Head of Old River
- San Joaquin River at Jersey Point
- Sacramento River at Rio Vista
- Sacramento River above Delta Cross Channel

The sensitivity analysis shown in Figure 3-7 included the following storm events under the No Project condition:

- A 1 percent AEP flood (100-year) for the Sacramento and San Joaquin river basins
- A 1 percent AEP flood (100-year) for the Sacramento River Basin and a 2 percent AEP flood (50-year) for the San Joaquin River Basin
- A 2 percent AEP flood (50-year) for the Sacramento River Basin and a 1 percent AEP flood (100-year) for the San Joaquin River Basin

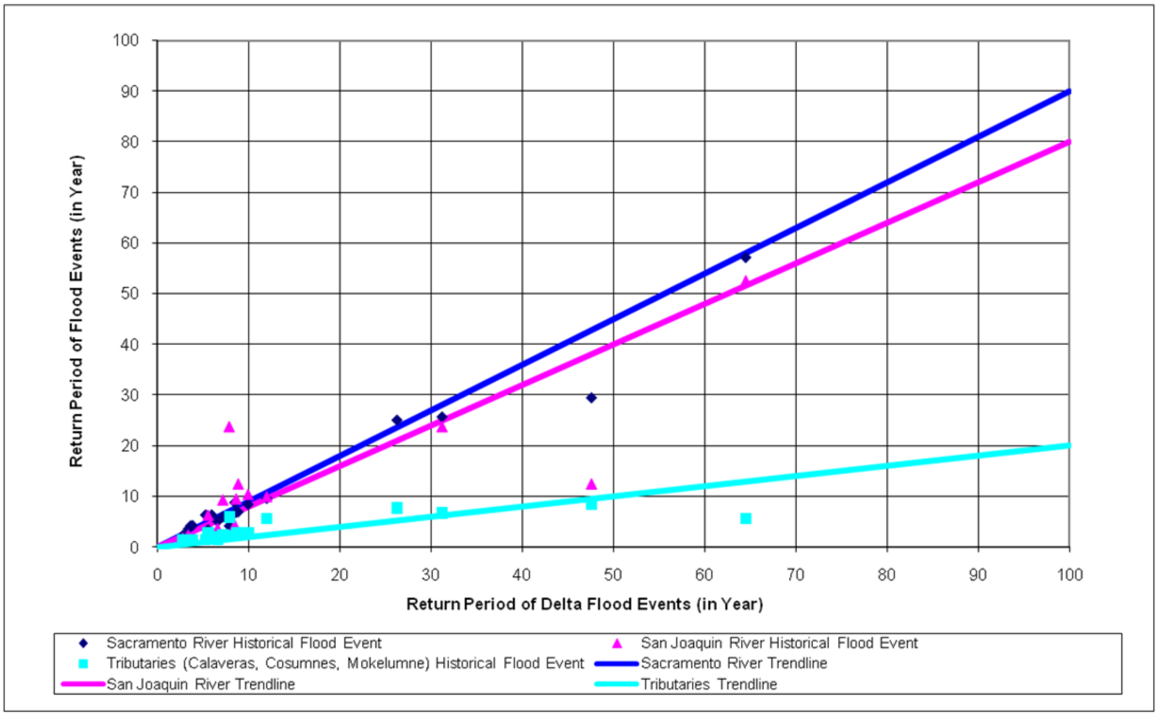


Figure 3-5. Correlation of Total Delta Inflow Recurrence with Source Inflows

As shown in Figure 3-8, for inflows into the RMA Delta Model from UNET results, the peak flow rate of the Sacramento River inflow (downstream from the American River confluence) to the RMA Delta Model for the 2 percent AEP event has a very similar magnitude to the 1 percent AEP event (Figure 3-8). For the Yolo Bypass inflow to the RMA Delta Model (Yolo Bypass at Lisbon), the difference between the flow rates of the 1 percent and 2 percent AEP events is less than 10 percent. For the San Joaquin River inflow to the RMA Delta Model (San Joaquin River upstream from the Paradise Cut Weir), the peak flow of the 1 percent AEP event is about 30 percent higher than the 2 percent AEP event.

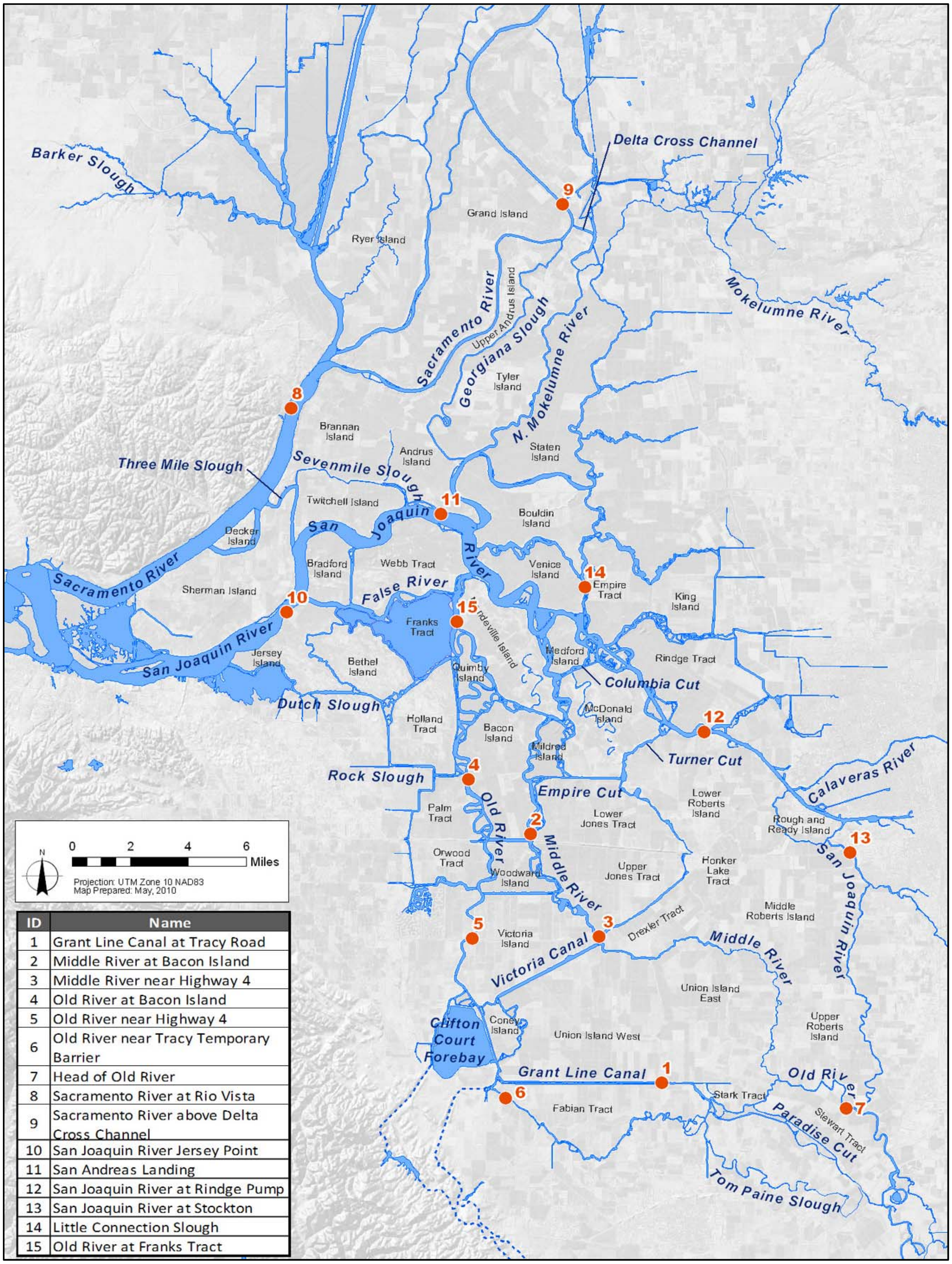


Figure 3-6. RMA Delta Model Output Locations

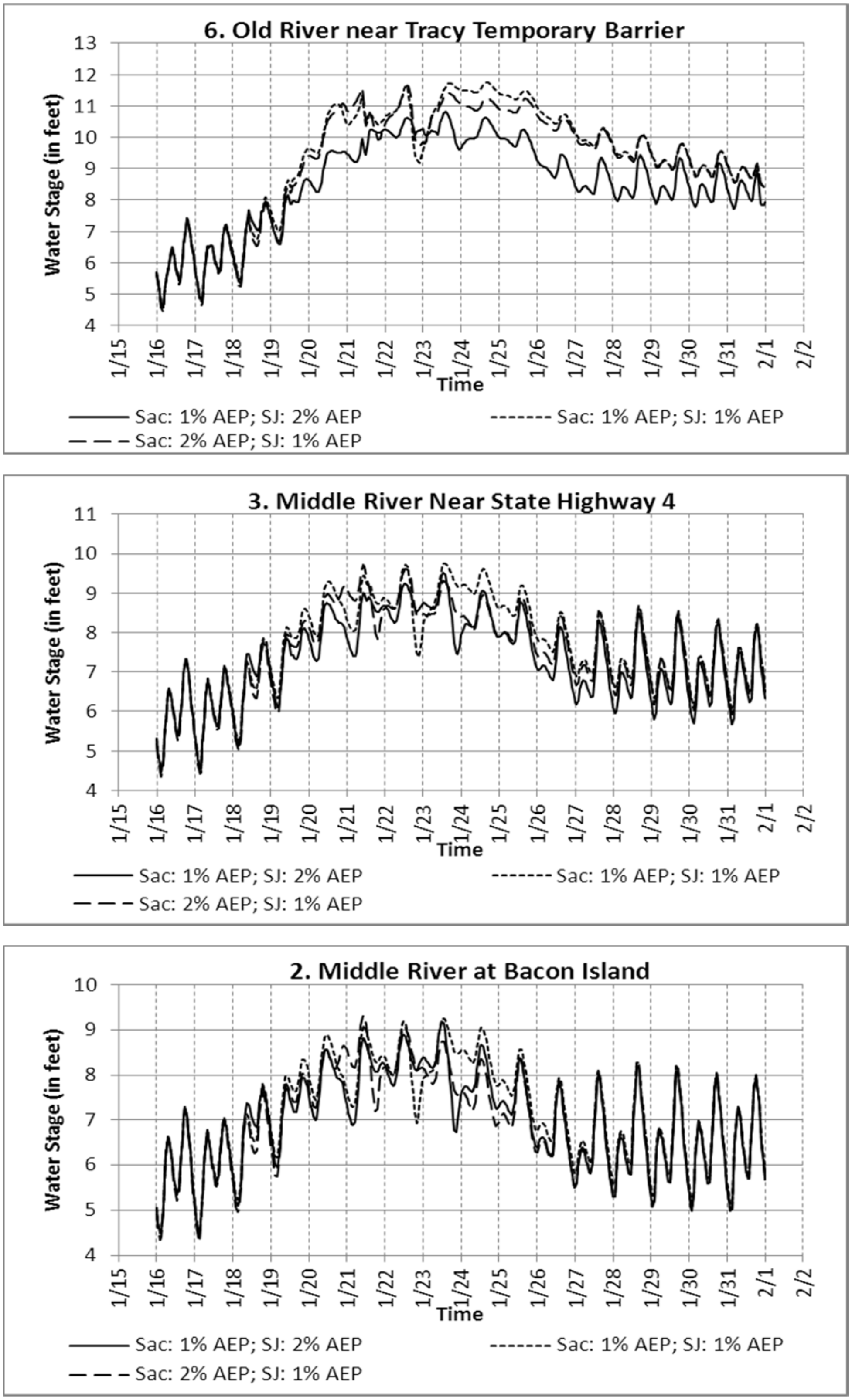
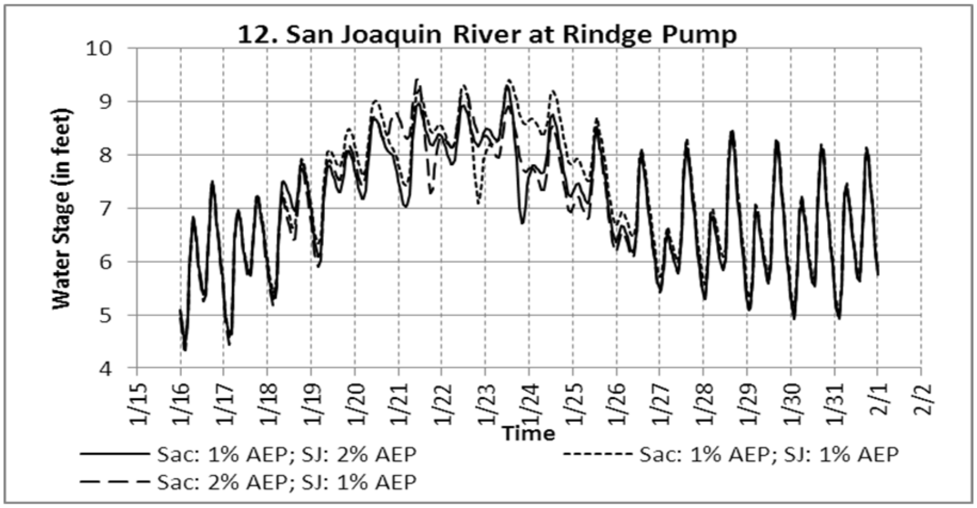
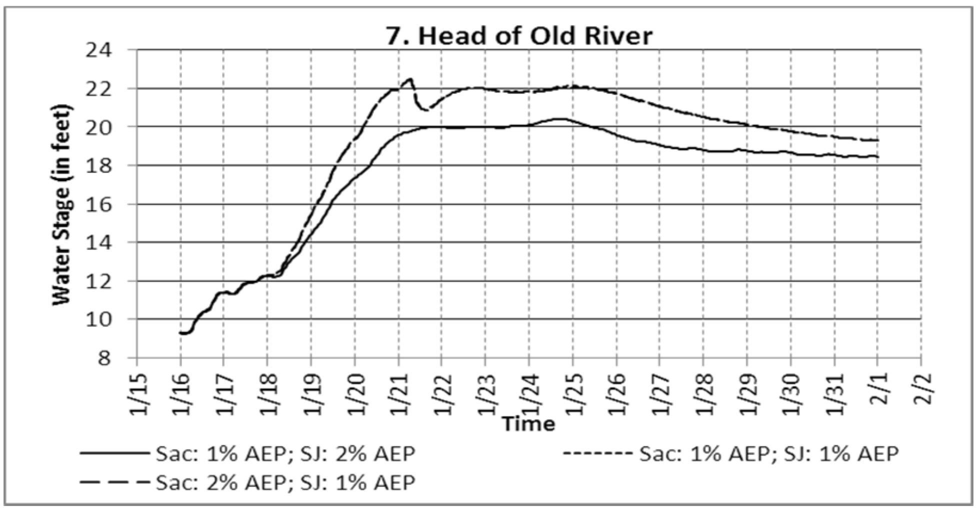


Figure 3-7. Simulated Delta Stages for Hydraulic Sensitivity Analysis





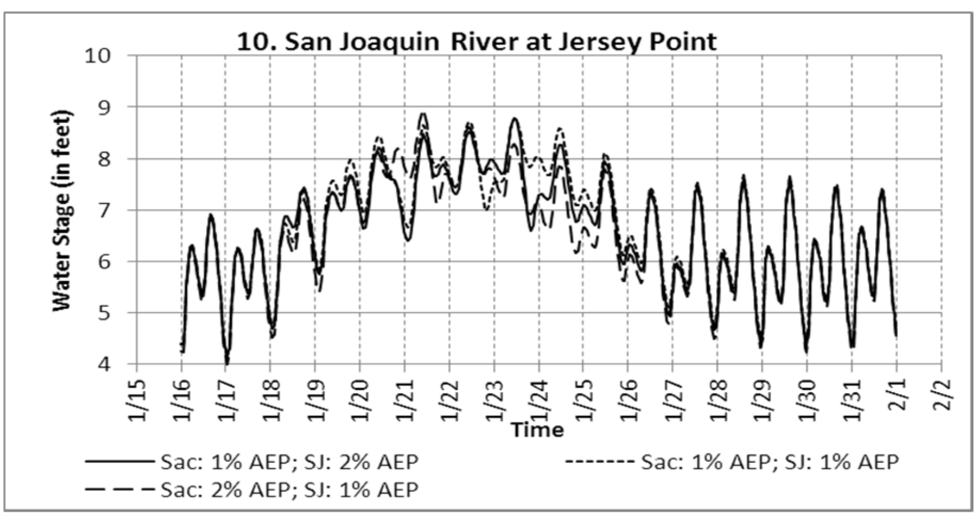
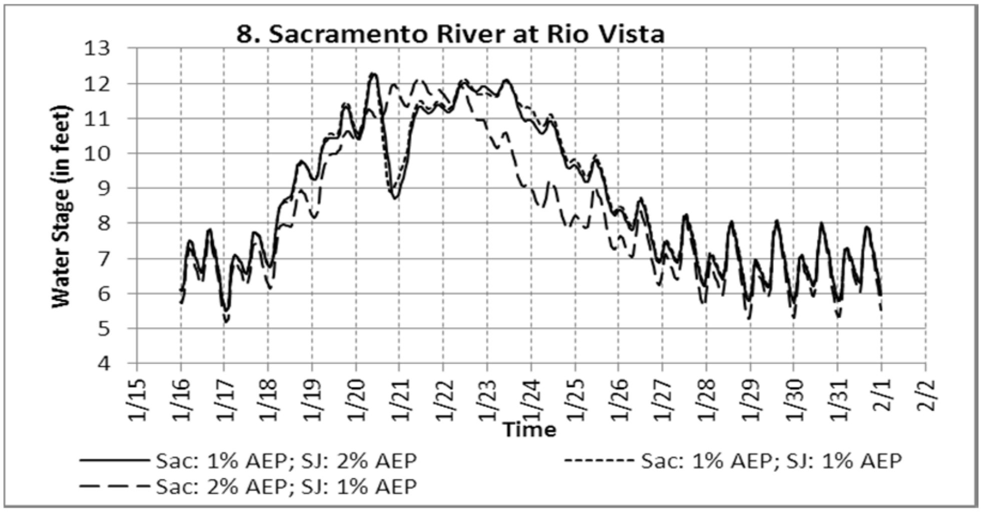


Figure 3-7. Simulated Delta Stages for Hydraulic Sensitivity Analysis (contd.)



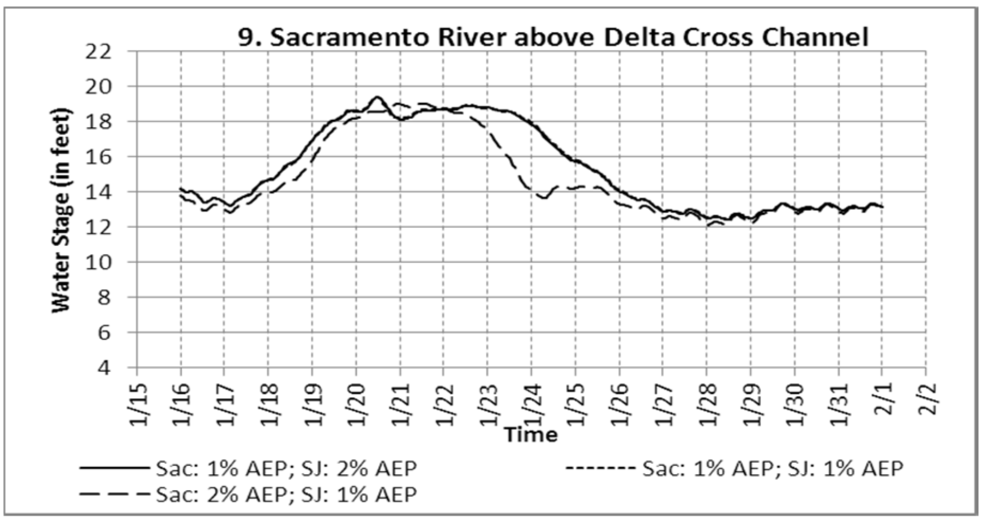


Figure 3-7. Simulated Delta Stages for Hydraulic Sensitivity Analysis (contd.)

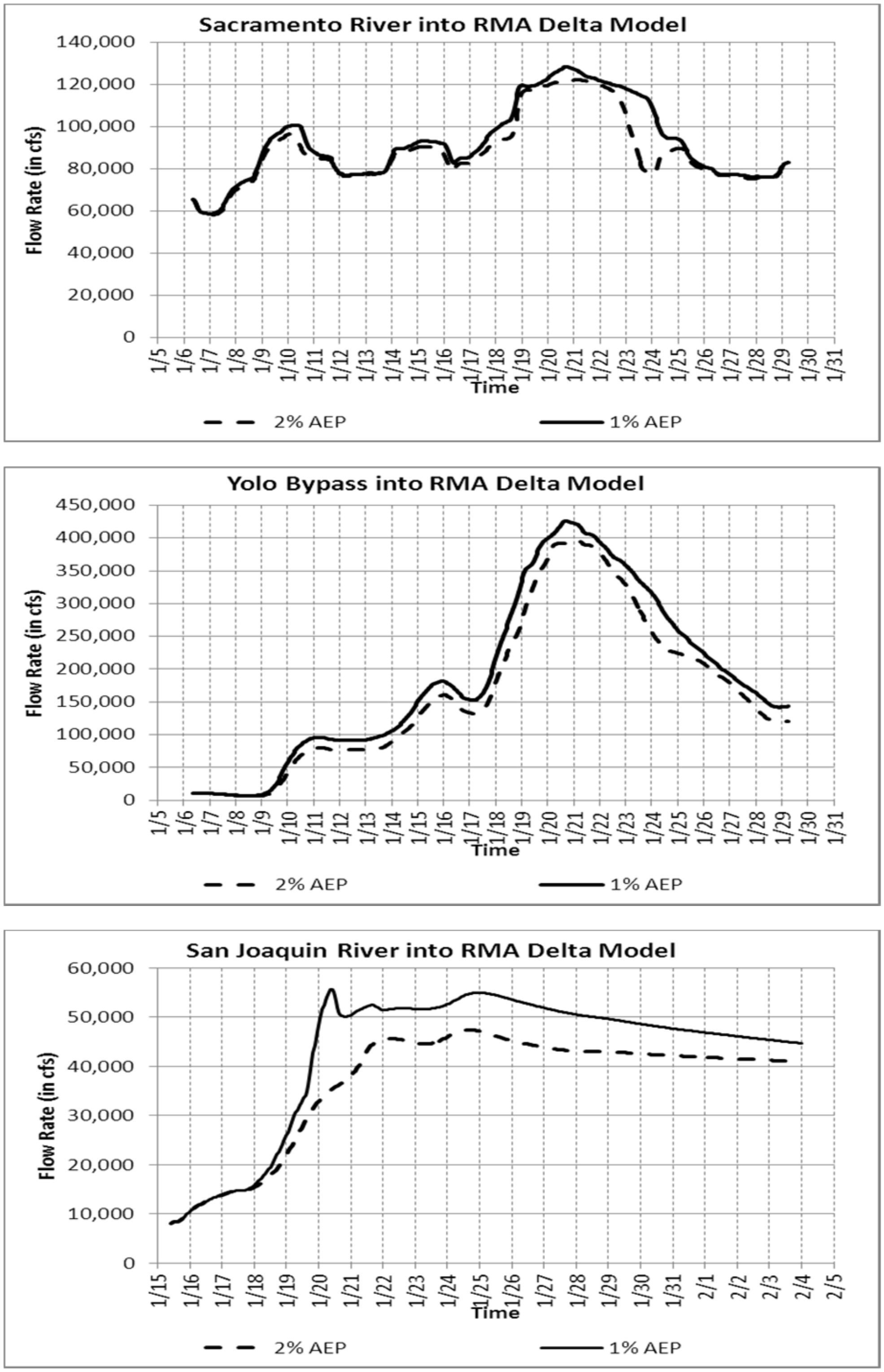


Figure 3-8. RMA Delta Model Inflows at Annual Exceedence Probability of 1 Percent and 2 Percent

The sensitivity analysis yields the following observations:

- Stages at locations in the Delta that are closer to the Sacramento River or Yolo Bypass (e.g., Rio Vista) demonstrated high sensitivity to Sacramento River inflows and very low sensitivity to San Joaquin River inflows.

- Stages at locations in the Delta that are closer to the San Joaquin River (e.g., head of Old River) demonstrated higher sensitivity to San Joaquin River inflows and very low sensitivity to Sacramento River inflows.

- Stages at locations in the Delta closer to Martinez (e.g., Jersey Point), increased with rising inflows during the peak inflow period (between January 19 through 23). However, the peak stage varied within 1 foot under different inflows from the two river basins. Stages at these locations also demonstrated very high sensitivity to tidal stages.

After looking at the results of the historical review and the sensitivity analysis, it was determined that Delta stage analysis would be based on inflows from the two river basins, as well as tributary flows for the same AEP.

3.4.4 Simulation Period

The Sacramento River UNET model simulation period was from January 6 through 29, with peak flows for all flood events occurring between January 18 and 20. The San Joaquin River UNET model simulation period was from January 15 through February 3, with peak flows for all flood events occurring between January 18 and 20.

For the RMA Delta Model, the simulation period for the 1, 0.5, and 0.2 percent AEP events was from January 7 through January 31. The simulation period for the remaining AEP events was from January 7 through February 3 so that river peak stages had passed through the Delta by the end of the simulation period.

Because the Delta simulation period extended beyond the simulation period for the Sacramento River UNET model, Sacramento River and Yolo Bypass inflows to the Delta were extended by repeating the last flow rates of the period beyond the UNET simulation period (i.e., the flow rate for January 29 was repeated for the period of January 30 through January 31 for 1, 0.5, and 0.2 percent AEP events, and through February 3 for the remaining events). Similarly, inflows to the Delta from the San Joaquin River UNET model were extended by repeating the very first flow rate for the period before the UNET simulation period.

3.4.5 Levee Breach Location and Elevation

In the RMA Delta Model, by default, a boundary or shoreline is represented as an "infinite wall" where no overtopping flow is allowed. To simulate levee overtopping, levee failures, and resulting island flooding, network elements representing river channels were connected to Delta island elements with "weir elements." Levee failure was modeled by changing the weir elevation over time on a node-by-node basis to allow complete simulation of a levee failure event. Flow over a levee can transition from free weir flow to submerged weir flow and finally to simple friction loss using a Manning's "n" formula. The RMA model now allows levees to overtop without failure or permits the initiation of levee failure when a threshold water surface elevation is reached.

It is assumed that when river stage is higher than the levee crest of an island, the levee will begin to breach and water will flow into the island until water stage inside and outside the island is in equilibrium. For each Delta island, levee crest elevations were taken approximately every 1,500 feet along the levee from DWR 2008 Light Detection and Ranging (LiDAR) data (URS, 2011). The breach location for each island was selected through the following steps:

- **Step 1 –** Use the RMA Delta Model with "infinite walls" (i.e., no levee overtopping or breaches) to simulate maximum river stage under the 0.5 percent AEP event of the Achieve SPFC Design Flow Capacity Approach.[3] From the Riverine Studies, the SPFC approach resulted in the largest stage increases into the Delta.
- **Step 2 –** Calculate overtopping as the difference between the peak river stage and levee crest elevation.
- **Step 3 –** Use the location of the maximum overtopping difference from Step 2 as the levee breach location.

The UNET and RMA Delta models overlap at their downstream and upstream ends, respectively. For islands that were simulated in both the RMA Delta Model and the UNET models (see Figure 3-4), levee breach simulation in the RMA Delta Model was based on the same assumptions for levee breach location and elevation as in the UNET models.

[3] Boundary inflow for this event represents the most conservative river flow conditions—that levees upstream do not fail until river stage exceeds the SPFC design flow capacity.

3.5 Assumptions for Achieve SPFC Design Flow Capacity Approach

Changes in modeling assumptions from the No Project condition in the RMA Delta Model for the Achieve SPFC Design Flow Capacity Approach included changing levee breach elevations for SPFC levees to match the SPFC design profile plus three feet of freeboard and using different upstream boundary condition inflows from the Achieve SPFC Design Flow Capacity UNET models of the Sacramento and San Joaquin rivers.

3.6 Assumptions for Protect High Risk Communities Approach

Changes in modeling assumptions from the No Project condition in the RMA Delta Model for the Protect High Risk Communities Approach included changing levee breach elevations for any high risk community levees and using different upstream boundary condition inflows from the Protect High Risk Communities UNET models of the Sacramento and San Joaquin rivers.

3.7 Assumptions for Enhance Flood System Capacity Approach

Changes in modeling assumptions from the No Project condition in the RMA Delta Model for the Enhance Flood System Capacity Approach included Paradise Cut Bypass modifications, transitory storage on Roberts Island, and different upstream boundary condition inflows from the Enhance Flood System Capacity UNET models of the Sacramento and San Joaquin rivers.

3.7.1 Paradise Cut Bypass Modifications

The following improvements to Paradise Cut to increase its capacity to divert water during the high-flow conditions were made in the RMA Delta Model as part of the Enhance Flood System Capacity Approach (see Figure 3-9):

- Removal of about 4 feet of soil from an existing elevated terrace in the reach of Paradise Cut downstream from the weir to the upstream side of the Union Pacific Railroad (UPRR) crossing to lower the tailwater for the Paradise Cut Weir, allowing more flow to be diverted from the San Joaquin River over the weir.

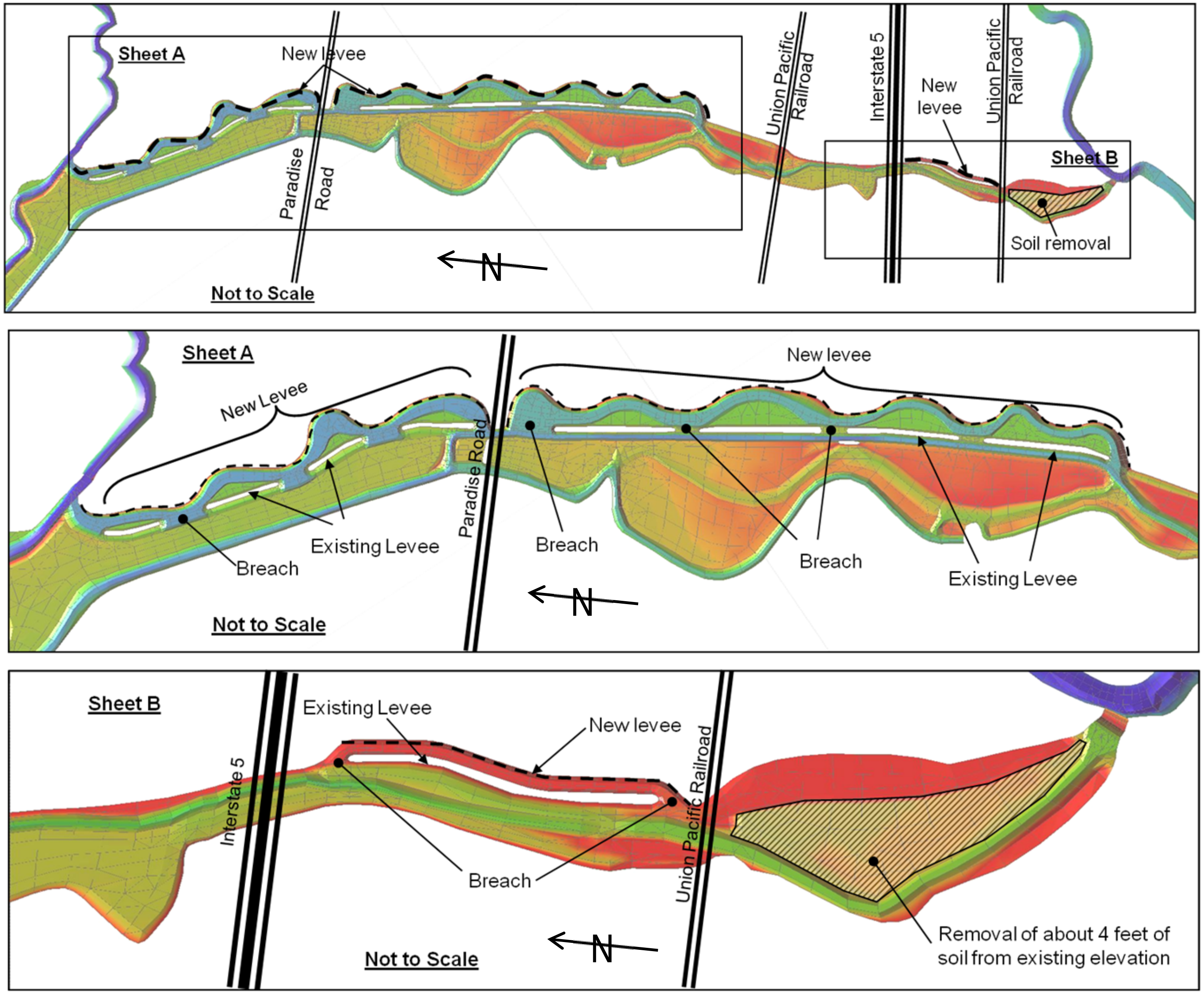


Figure 3-9. Paradise Cut Bypass Configuration

- Construction of a new levee set back about 150 feet from the existing levee on the right bank of Paradise Cut between the UPRR crossing and Interstate 5, with breaches in the existing levee to increase the carrying capacity of Paradise Cut without a corresponding stage increase. The rest of the existing levee would remain as an in-channel island for ecological restoration area.

- Construction of a new levee set back 150 to 900 feet from the existing levee on the right bank of Paradise Cut from downstream of the western Union Pacific Railroad crossing to the Paradise Road crossing. The existing levee would remain but would be breached in several locations, and the area between the existing and new levees would be excavated down to an elevation of 3.0 feet below mean sea level (msl) to form a marsh area for ecological restoration.

- Construction of a new setback levee with levee breaches in the existing levee between Paradise Road and the confluence of Paradise Cut with Old River similar to the section just upstream, except that the area between the existing and new levees would be excavated to an elevation of 5.0 feet below msl to form a marsh area for ecological restoration.

3.7.2 Roberts Island Transitory Storage

Roberts Island transitory storage is to provide about 69,000 acre-feet of storage on 8,800 acres on Upper and Middle Roberts Island for the 1 percent AEP and larger flood events. Floodflows would enter the Roberts Island transitory storage area over a new weir in the levee on the left bank of the San Joaquin River and would be stored until the river subsides to a stage that no longer threatens the metropolitan Stockton area. Stored water would be released back to the San Joaquin River through a new outlet. The following are improvements or additions (see Figure 3-10) for this new transitory storage area:

- Levee repairs along the left bank of San Joaquin River and the right banks of the Middle and Old rivers.

- Construction of a 3,000-foot-long concrete weir (crest height 16.28 feet NGVD29) on the left bank of the San Joaquin River about 2.25 miles downstream from the confluence of the San Joaquin River and Old River.

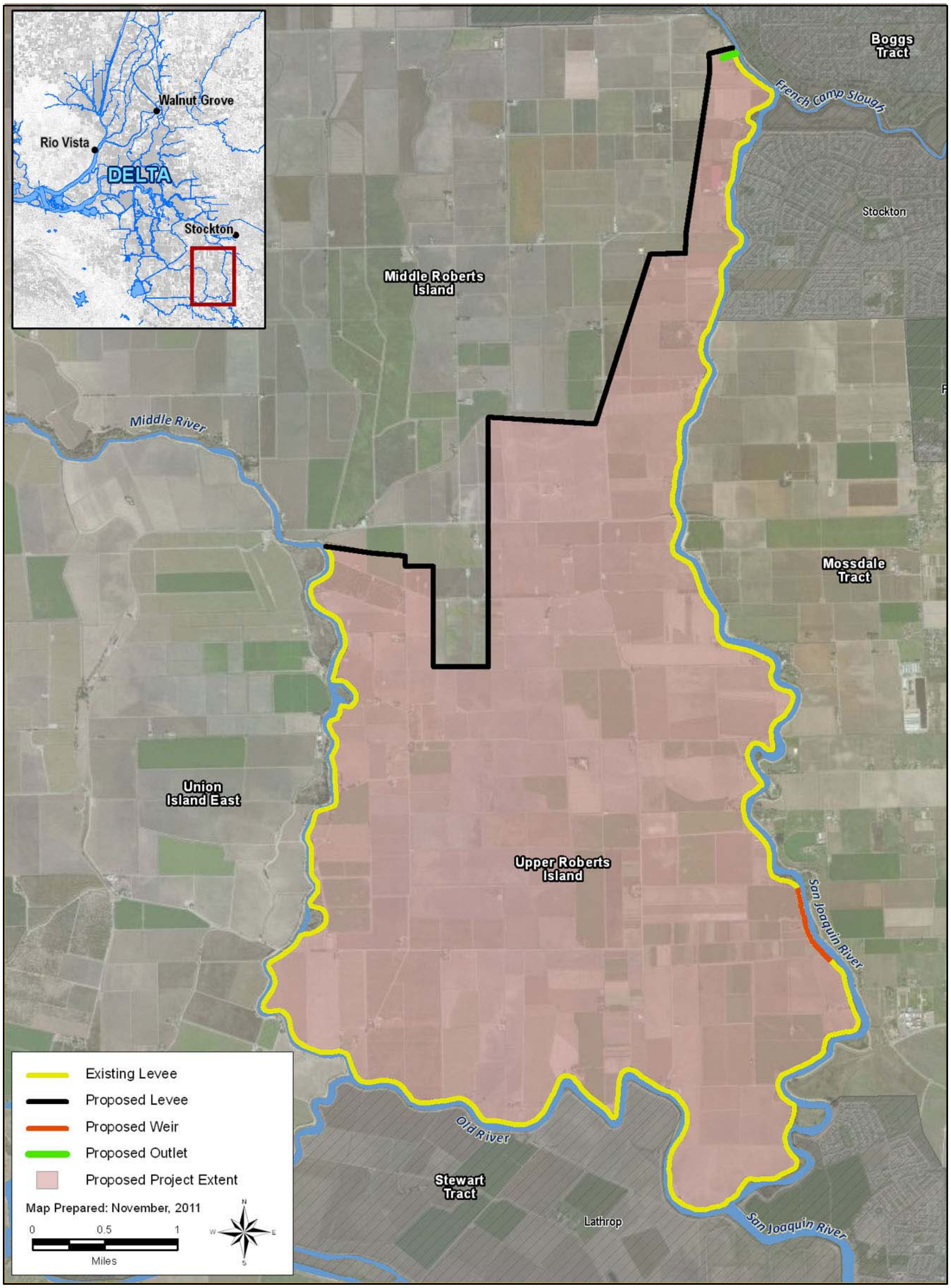


Figure 3-10. Roberts Island Transitory Storage

- Construction of a new 7.4-mile-long levee (crest height about 16.5 feet NGVD29) through the center of Roberts Island to connect the left bank of the San Joaquin River with the right bank of Old River and to separate Middle Roberts Island from Lower Roberts Island. The new levee is necessary because the land surface elevation of Lower Roberts Island is below sea level, and removing any stored water from Lower Robert Island would require pumping, instead of gravity drainage, as is the case with Upper and Middle Robert Island.

- Construction of a gated outlet structure at the northeast corner of Middle Roberts Island, just south of State Highway 4 to accommodate a maximum 2,500 cfs return flow to the San Joaquin River at various stages.

3.8 Assumptions for State Systemwide Investment Approach

Changes in modeling assumptions from the No Project condition for the RMA Delta Model for the State Systemwide Investment Approach included changing levee breach elevations for any high risk community levees, Paradise Cut Bypass modifications (see Section 3.7.1), and using different upstream boundary condition inflows from the State Systemwide Investment Approach UNET models of the Sacramento and San Joaquin rivers.

3.9 Model Limitations

Understanding and applying the results of any model requires an understanding of the limitations of the model. Limitations associated with the RMA Delta Model are as follows:

- Levee breach locations and elevations were predetermined. Once river stage at a predetermined location exceeded the designated elevation, levee overtopping or failure and subsequent island flooding were simulated using 2-D weir elements.

- The RMA Delta Model for the CVFPP should not be used to predict actual levee failures because model inputs are deterministic (i.e., no randomness is involved in the model results, but actual levee failures are a matter of probability).

- River channels were represented by 1-D or 2-D elements to approximate reality and might potentially simplify the representation of the channel at certain locations.

- The RMA Delta Model does not represent flow hydraulics through bridges with the same level of detail as the HEC-RAS program.

- The RMA Delta Model is intended to be used to simulate Delta in-channel water stage and flood depth and flood volume of Delta islands. The water quality module of the RMA Delta Model was not used for the 2012 CVFPP modeling and, thus, flood-associated salinity and particle transport were not evaluated.

4.0 Results

Figure 4-1 indicates the locations in the Delta at which stage-frequency curves will be plotted to allow comparison of the operations of the flood management system among the No Project condition and the various approaches.

4.1 Stage-Frequency Curves

Figures 4-2 through 4-16 show stage-frequency curves for all of the approaches for the 15 selected output locations in the Delta (Figure 4-1).

Abbreviations are used on the stage-frequency plots to designate the the approaches, as follows:

- SPFC = Achieve SPFC Design Flow Capacity Approach
- PHRC = Protect High Risk Communities Approach
- EFSC = Enhance Flood System Capacity Approach
- SSIA = State Systemwide Investment Approach

4.2 Out-of-System Volumes

Figure 4-1 shows the names and locations of the Delta islands used to tabulate the volume of floodflows leaving the flood management system during a given flood. Tables 4-1 through 4-5 contain the out-of-system volume for the No Project condition and each of the approaches in each of the islands. These out-of-system volumes are instrumental in understanding the function of the flood management system in the Delta. For example, the stage at a given location may be lower for the 100-year flood than for the 50-year flood. If islands upstream from or in the vicinity of this location are reviewed and a significant increase is observed in out-of-system volume between the 50- and the 100-year floods, it can be concluded that a levee breach upstream from the location has reduced the flows to a level less than the 50-year flow.

Another example would be a location where the stage between No Project condition and one of the approaches increases significantly for the same

AEP flood. Again, if upstream out-of-system volume is reduced, it can be concluded that additional flow remains in the river because upstream levees may have been reconstructed or raised and no longer breach as they did in the No Project condition.

4.3 Findings

There are 15 model output locations in the Delta (see Figure 4-1). Two locations are on the Sacramento River; four are on the San Joaquin River; five are on Old River; two are on Middle River; and one each on Grant Line Canal, and Little Connection Slough.

Figures 4-2 through 4-16 show stage-frequency curves for all of the approaches at each of the 15 selected output locations in the Delta.

4.3.1 Achieve SPFC Design Flow Capacity Approach

Restoring all SPFC levees to their design flow capacity for the Achieve SPFC Design Flow Capacity Approach would significantly reduce the number of levee breaks upstream from the Delta and would cause increased stages at all reporting locations in the Delta. The floodwaters that normally would leave the system through levee breaches in the No Project condition would be contained in the river channels and barring other levee breaches would continue downstream to the Delta in this approach. Island inundation from levee breaches would be greater than the No Project condition for AEPs as low as 1 percent. Island inundation would actually decrease for AEPs of 0.5 and 0.2 percent because of increased levee breaks in the downstream areas of the Sacramento and San Joaquin river basins.

4.3.2 Protect High Risk Communities Approach

The Protect High Risk Communities Approach modifies urban levees to pass the 200-year (0.5 percent AEP) flood with 3 feet of freeboard. Since it is only urban levees, and a few small communities, that are modified, stages in the Delta would remain essentially the same as for the No Project condition. Island inundation follows the same pattern and is much the same as the No Project condition except for the 0.5 and 0.2 percent AEP floods where urban areas that sustained a levee breaks in the No Project condition do not break, causing increased flows downstream, which would increase stages and result in increased island inundation in the Delta.

4.3.3 Enhance Flood System Capacity Approach

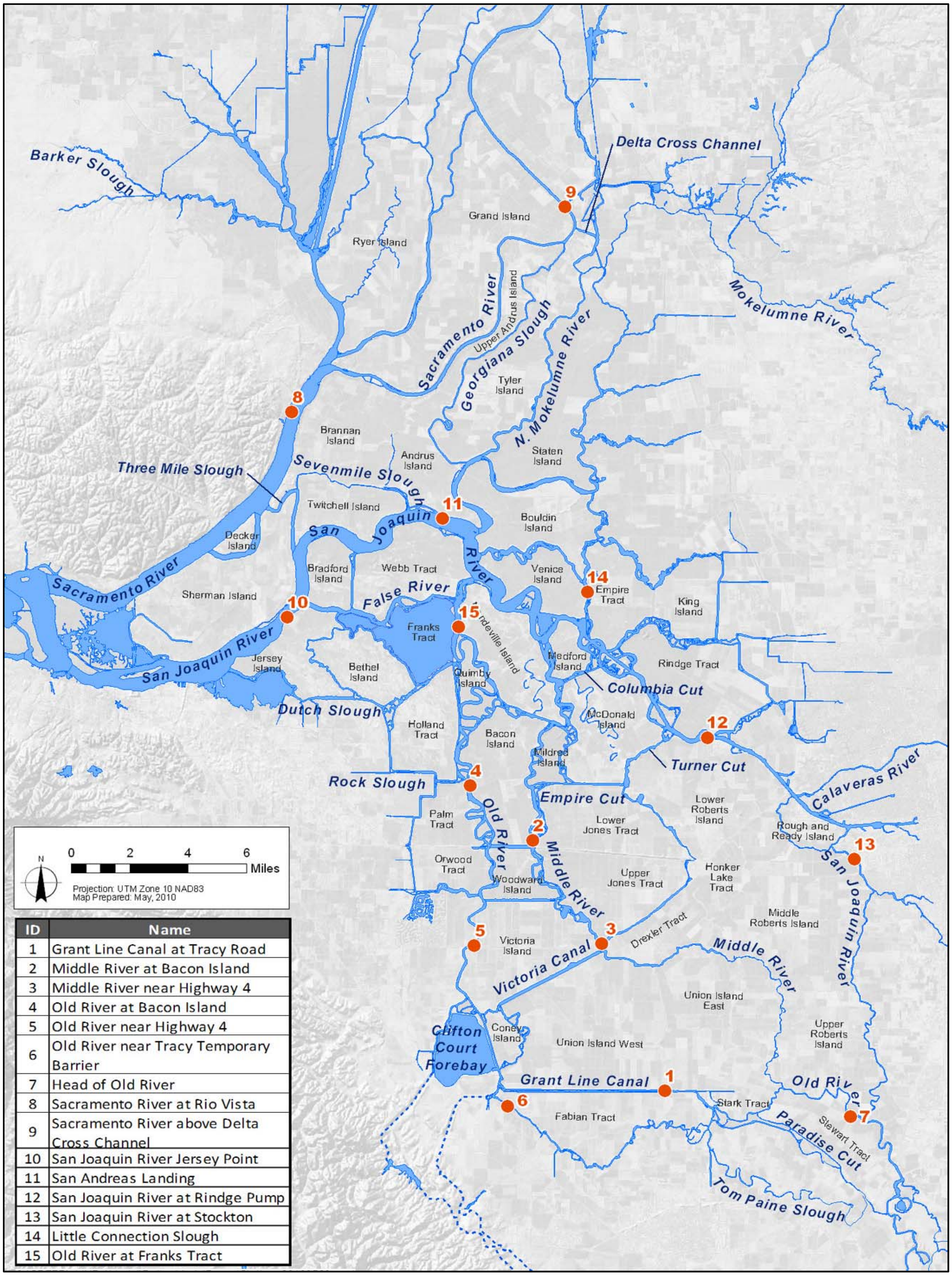
The Enhance Flood System Capacity Approach modifies urban levees to pass the 200-year (0.5 percent AEP) flood with 3 feet of freeboard. In addition, nonurban SPFC levees, including SPFC levees in the Delta, were modified to the 55/57 design profile (the design standard for construction of the State Plan of Flood Control) plus freeboard (3 feet), or the existing TOL elevation as determined by the ULE and NULE projects, whichever was greater. Other key components of the approach are added upstream reservoir storage, widened and new bypasses, levee setbacks, and floodplain storage.

Even though restoring all urban and SPFC levees as described above should result in additional flow volumes entering the Delta, flow volumes entering the Delta are significantly decreased for the 10, 4, 2, and 1 percent (10-, 25, 50-, 100-year) floods as a result of the added upstream reservoir and floodplain storage. For the 0.5 and 0.2 percent AEP (200- and 500-year) floods the reservoir and floodplain storage is not enough to prevent an increase in flow into the Delta.

Flooding in the Delta is less than for the No Project condition for all AEPs because for two reasons. First, more than a dozen of the islands that flood in the No Project condition have SPFC levees and thus are restored to their design profile for the Enhance Flood System Capacity Approach. Second, for more frequent floods (i.e., 10, 4, 2, and 1 percent AEP), there is flow entering the Delta and therefore lower stages. The combination of these two factors results in less Delta flooding for the Enhance Flood System Capacity Approach.

4.3.4 State Systemwide Investment Approach

The State Systemwide Investment Approach assumes the same improvements to urban levees as the Protect High Risk Communities Approach. In addition, a new bypass and widening of the Yolo and Sutter bypasses are included in the Sacramento River Basin, and Paradise Cut Bypass is widened in the San Joaquin River Basin. Stages in the Delta are similar to or lower than the Protect High Risk Communities Approach, except where changes to the bypasses modify stages. Island inundation is less than the No Project condition for all AEPs except for the 0.2 percent AEP that sustains a less than 1 percent increase in island inundation.



ID	Name
1	Grant Line Canal at Tracy Road
2	Middle River at Bacon Island
3	Middle River near Highway 4
4	Old River at Bacon Island
5	Old River near Highway 4
6	Old River near Tracy Temporary Barrier
7	Head of Old River
8	Sacramento River at Rio Vista
9	Sacramento River above Delta Cross Channel
10	San Joaquin River Jersey Point
11	San Andreas Landing
12	San Joaquin River at Rindge Pump
13	San Joaquin River at Stockton
14	Little Connection Slough
15	Old River at Franks Tract

Figure 4-1. RMA Delta Model Output Locations

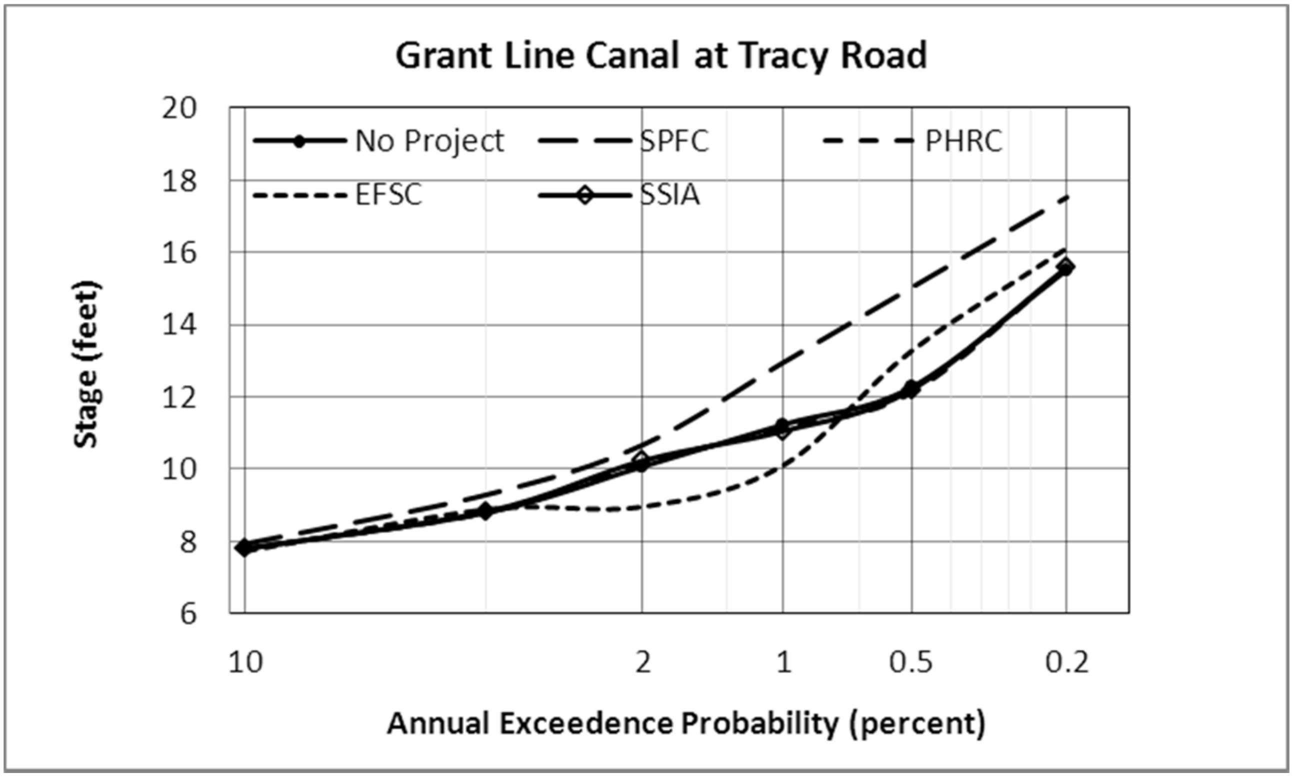


Figure 4-2. Stage-Frequency Curves: Grant Line Canal at Tracy Road [1]

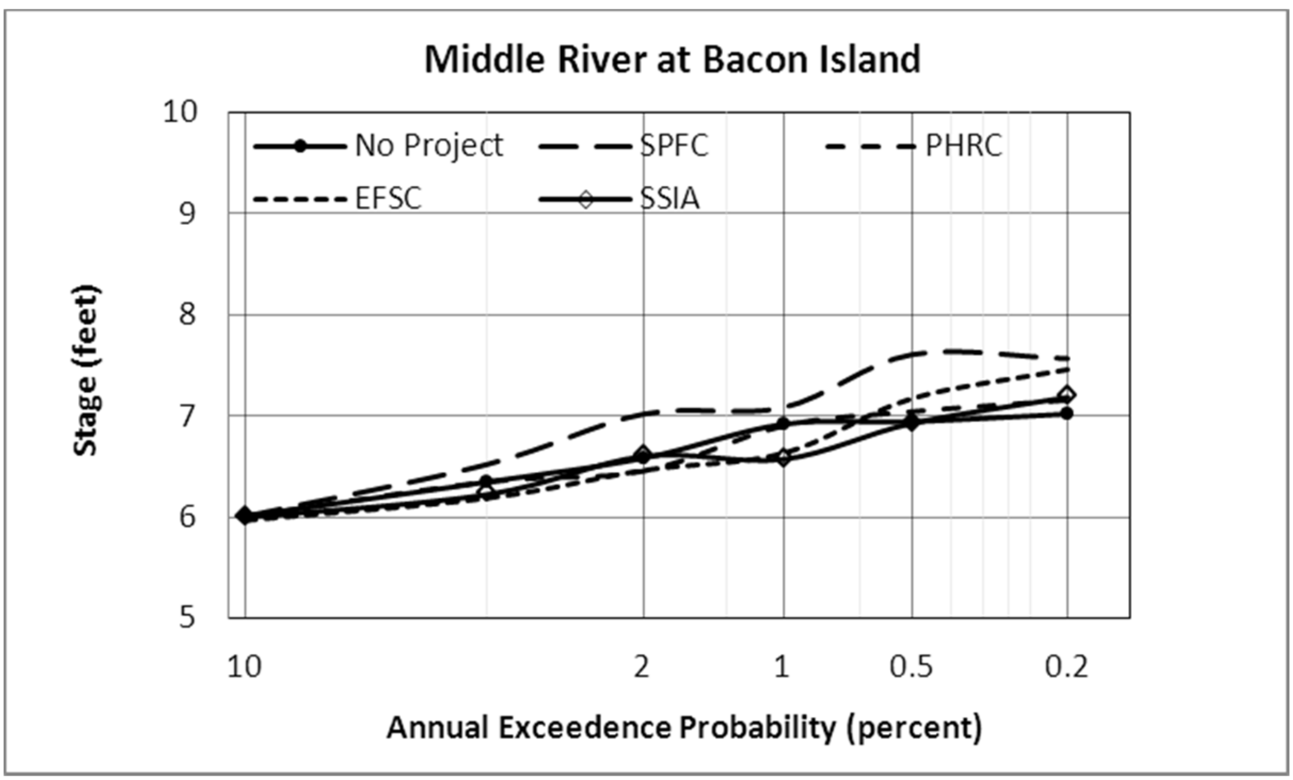


Figure 4-3. Stage-Frequency Curves: Middle River at Bacon Island [2]

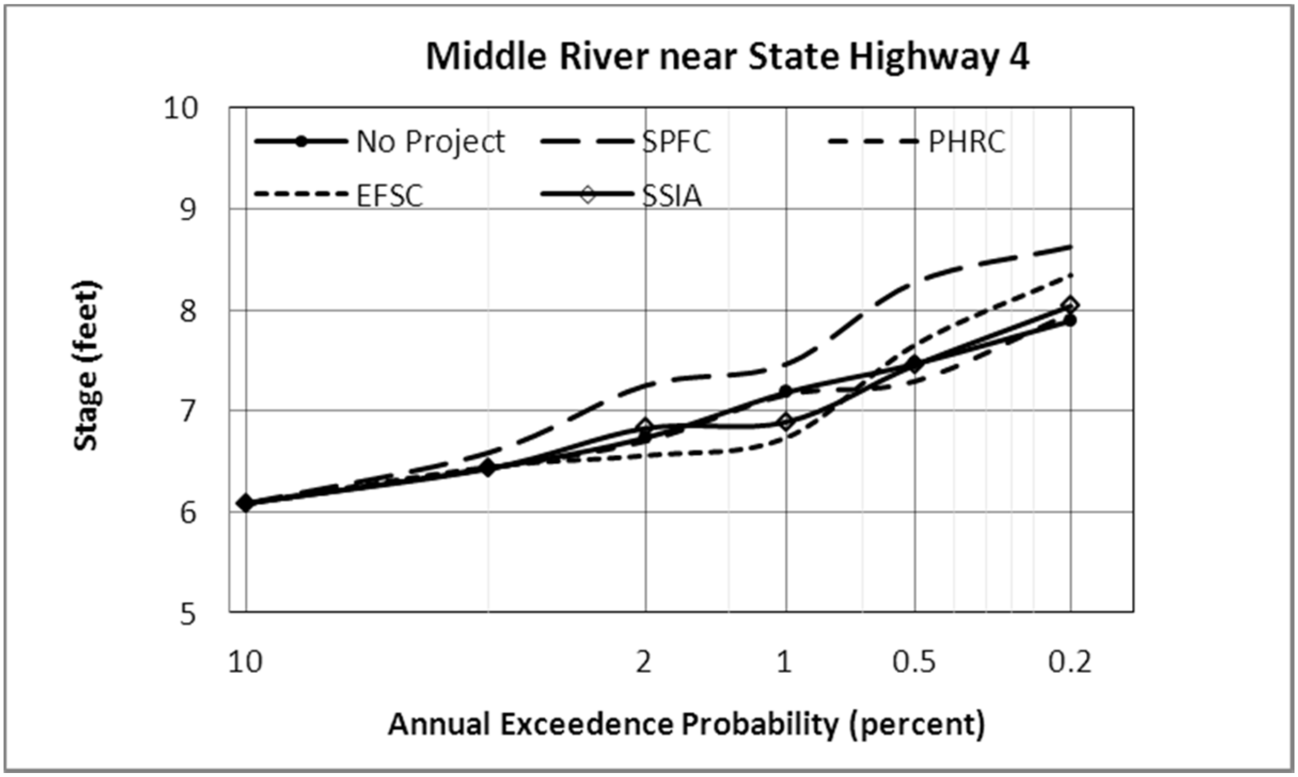


Figure 4-4. Stage-Frequency Curves: Middle River near State Highway 4 [3]

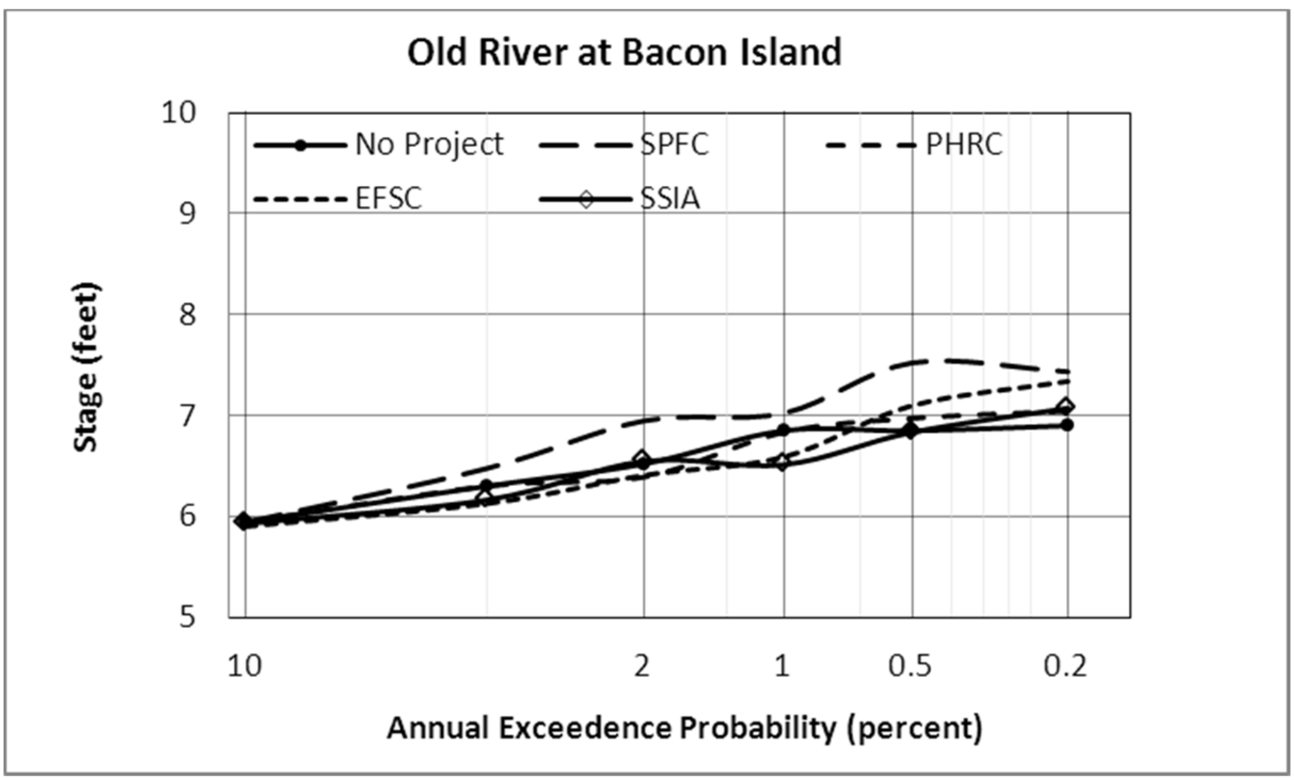


Figure 4-5. Stage-Frequency Curves: Old River at Bacon Island [4]

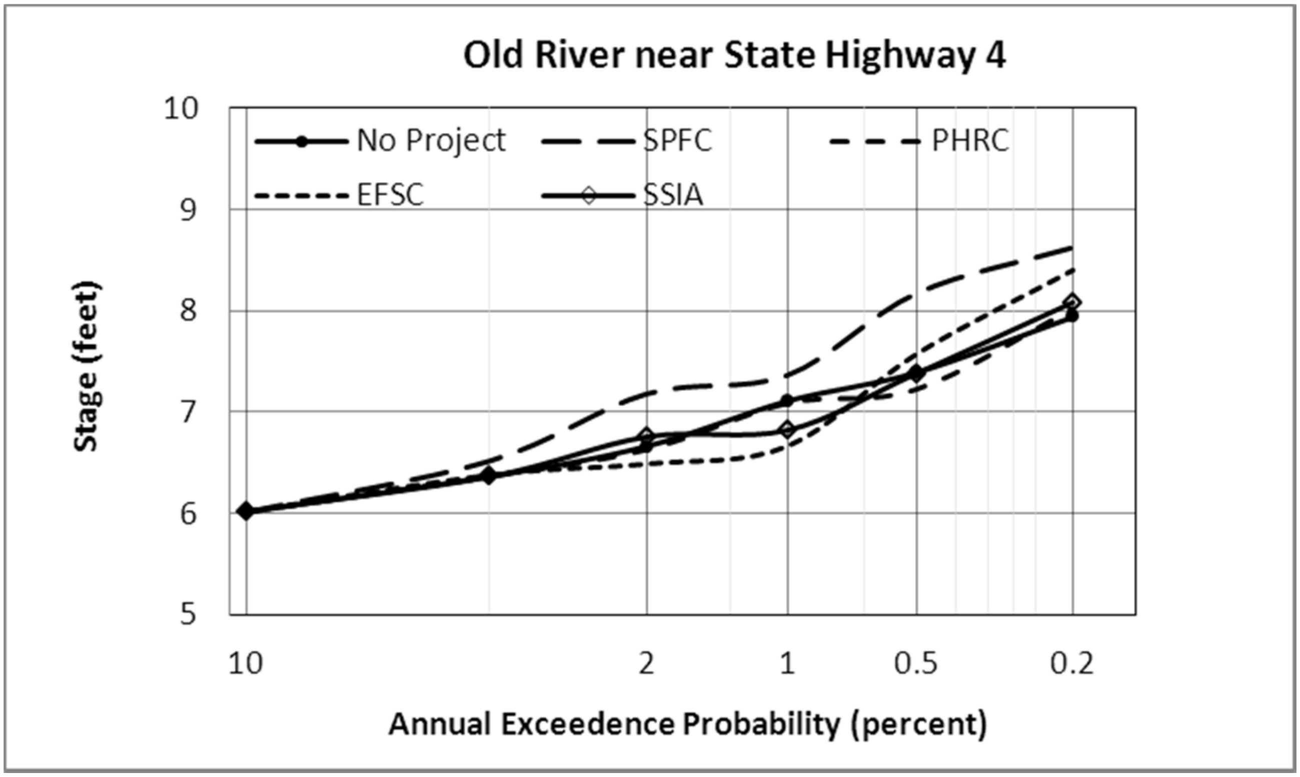


Figure 4-6. Stage-Frequency Curves: Old River near State Highway 4 [5]

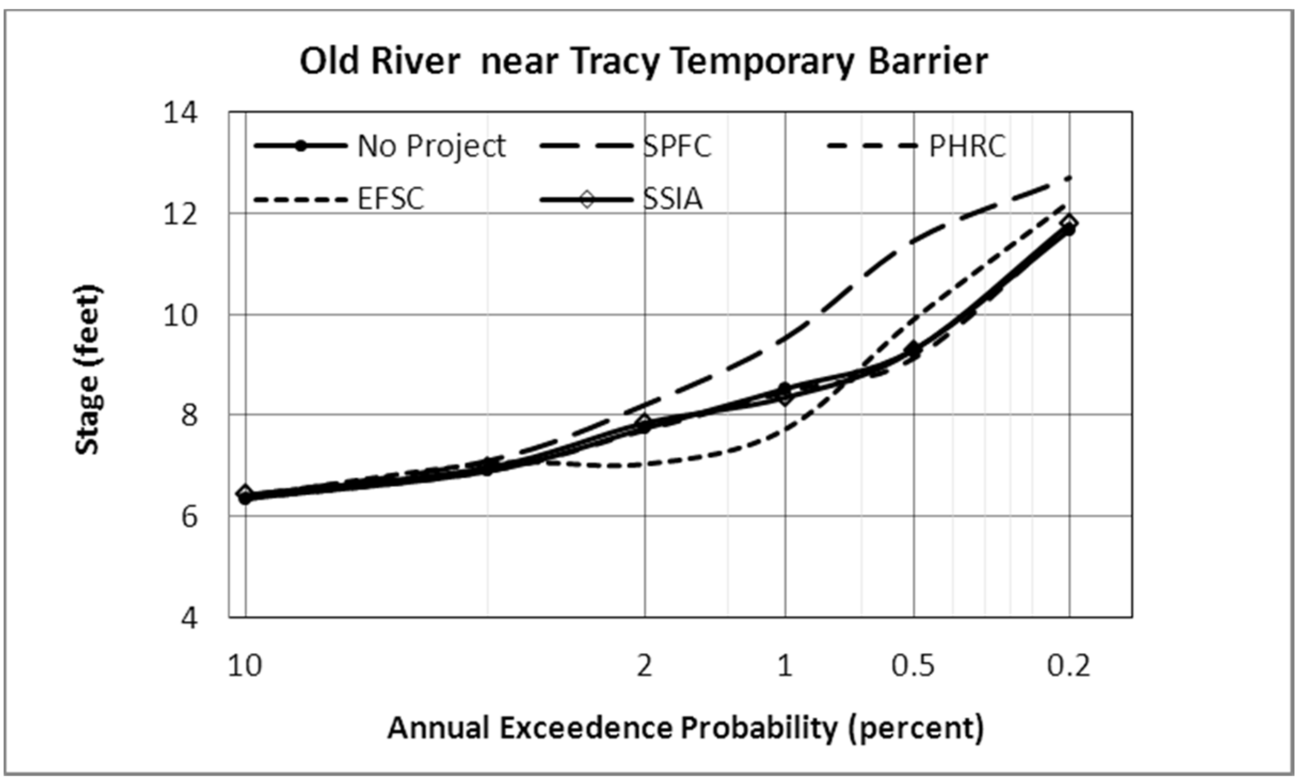


Figure 4-7. Stage-Frequency Curves: Old River near Tracy Temporary Barrier [6]

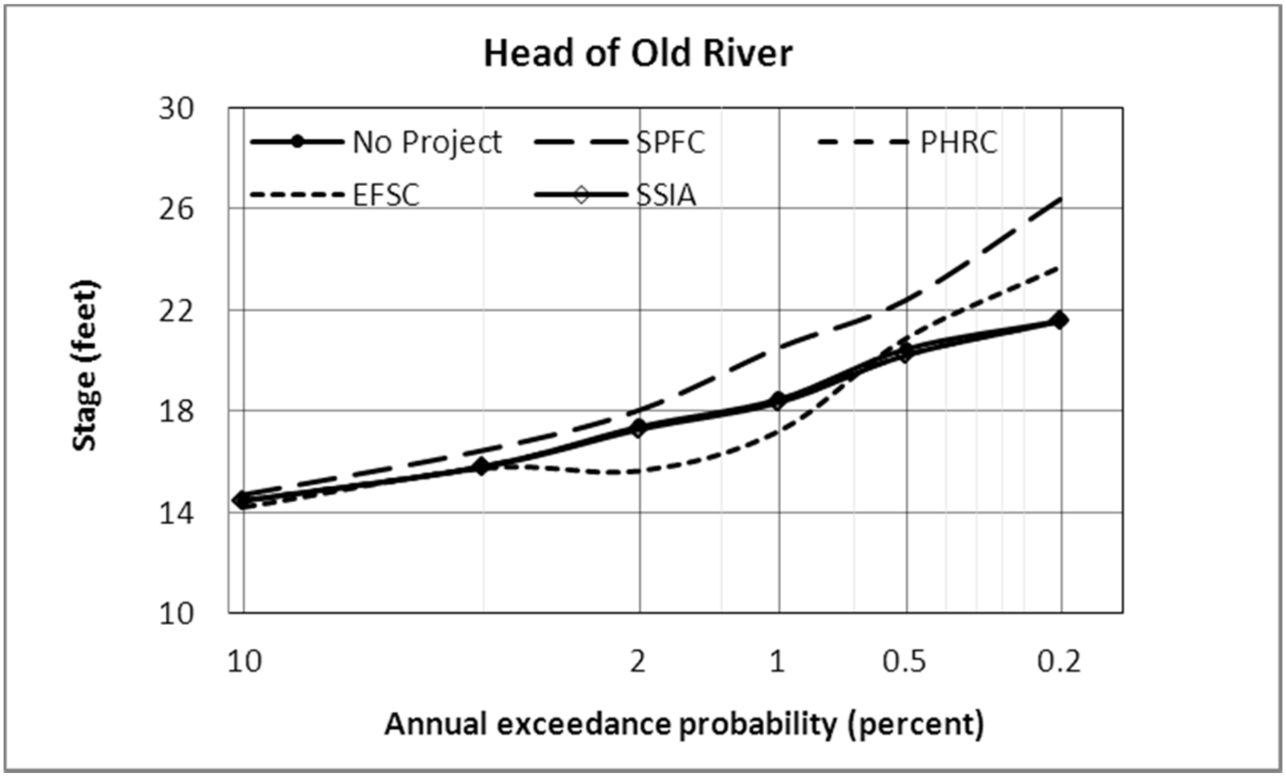


Figure 4-8. Stage-Frequency Curves: Head of Old River [7]

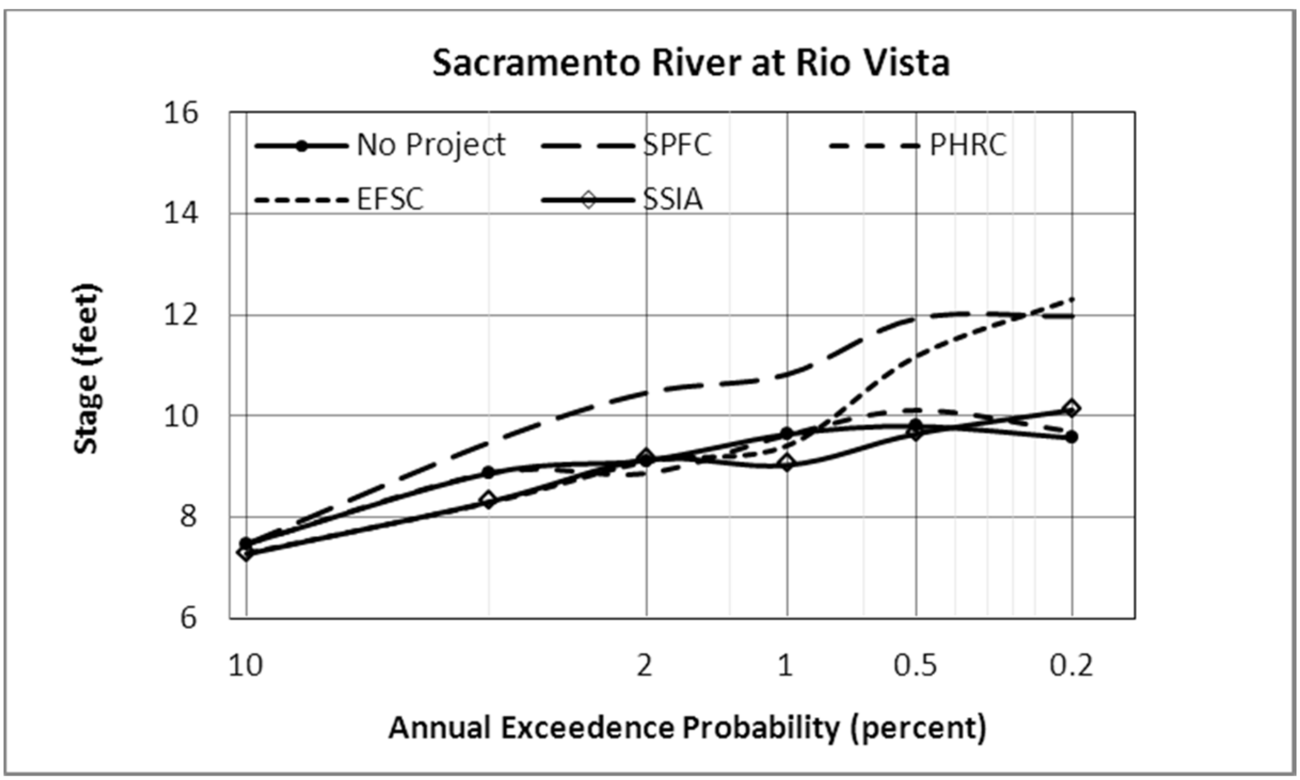


Figure 4-9. Stage-Frequency Curves: Sacramento River at Rio Vista [8]

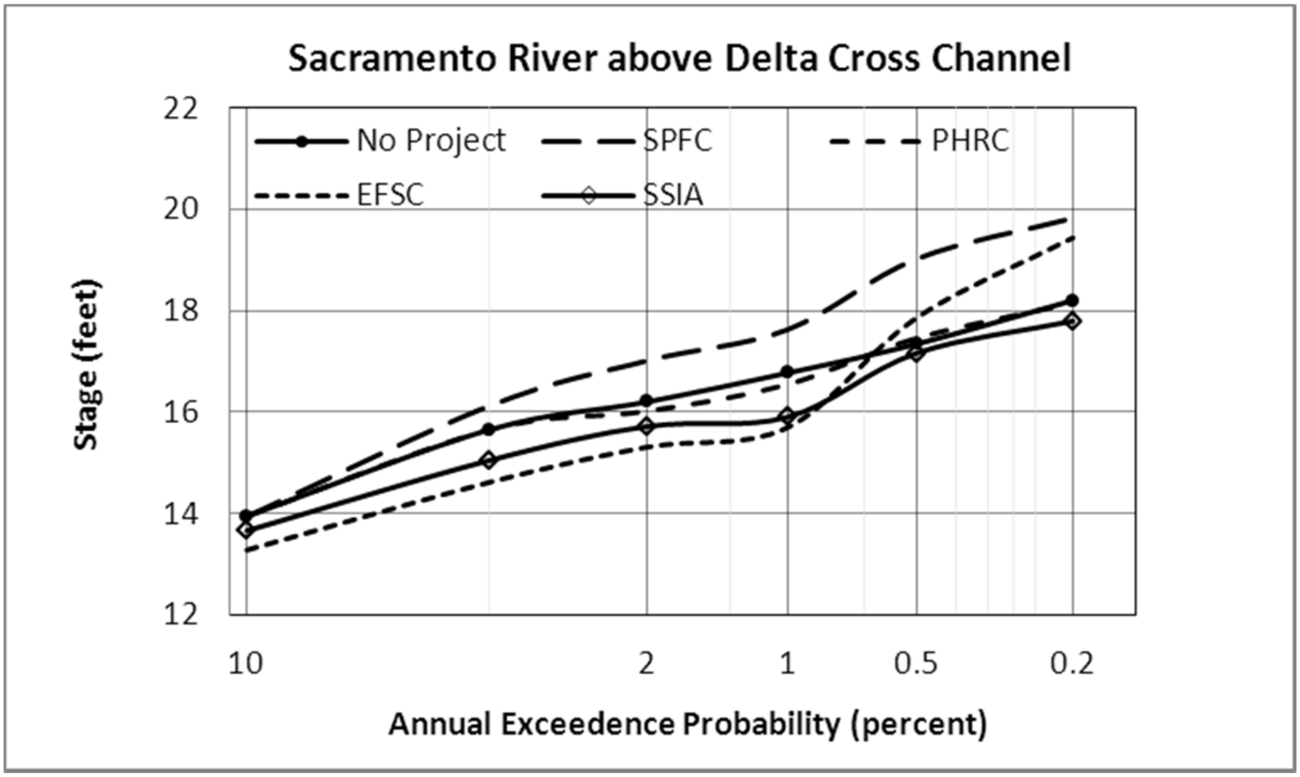


Figure 4-10. Stage-Frequency Curves: Sacramento River Above Delta Cross Channel [9]

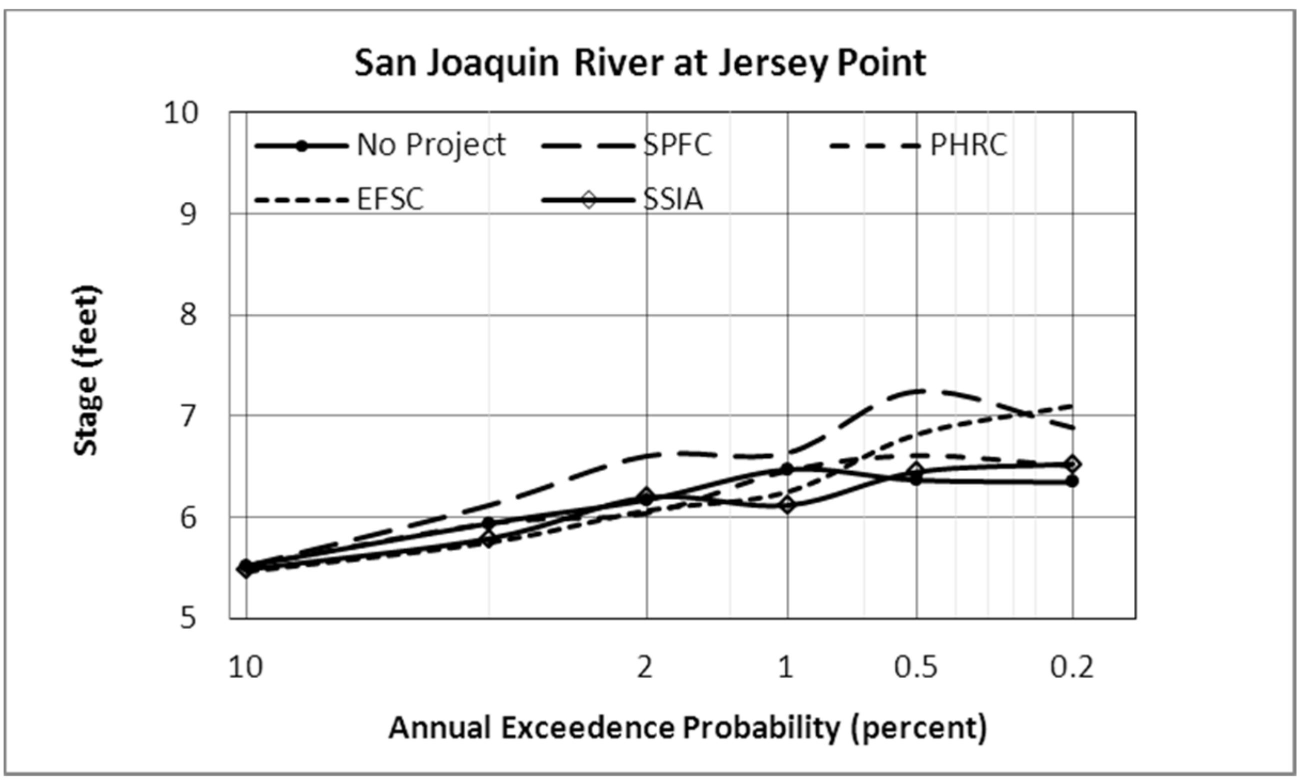


Figure 4-11. Stage-Frequency Curves: San Joaquin River at Jersey Point [10]

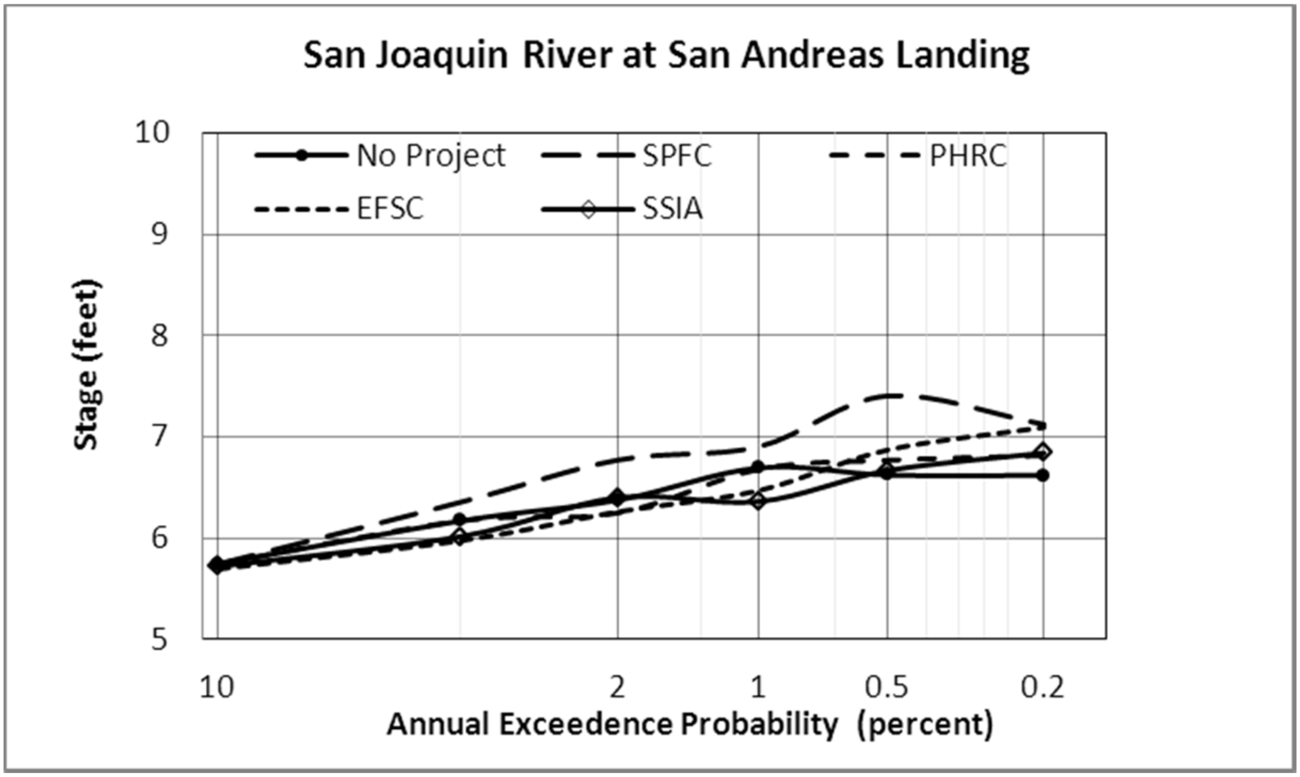


Figure 4-12. Stage-Frequency Curves: San Joaquin River at San Andreas Landing [11]

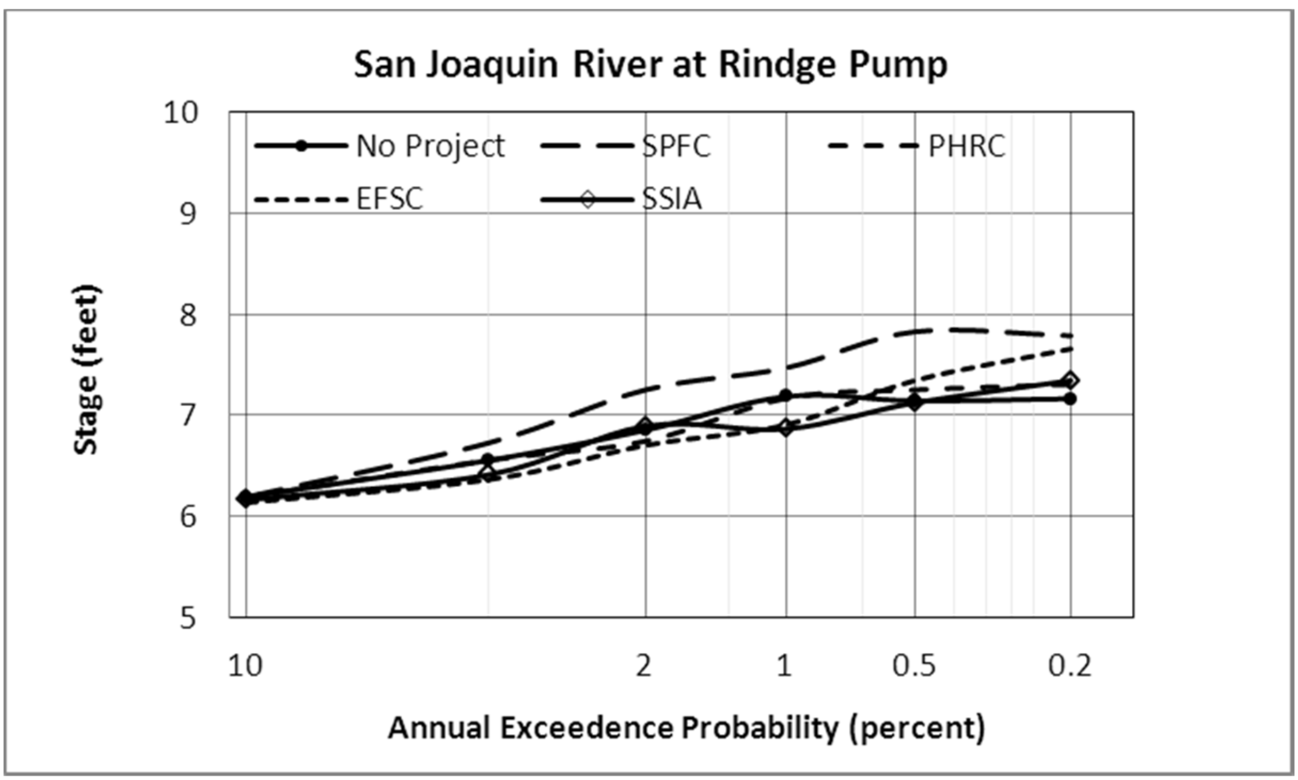


Figure 4-13. Stage-Frequency Curves: San Joaquin River at Rindge Pump [12]

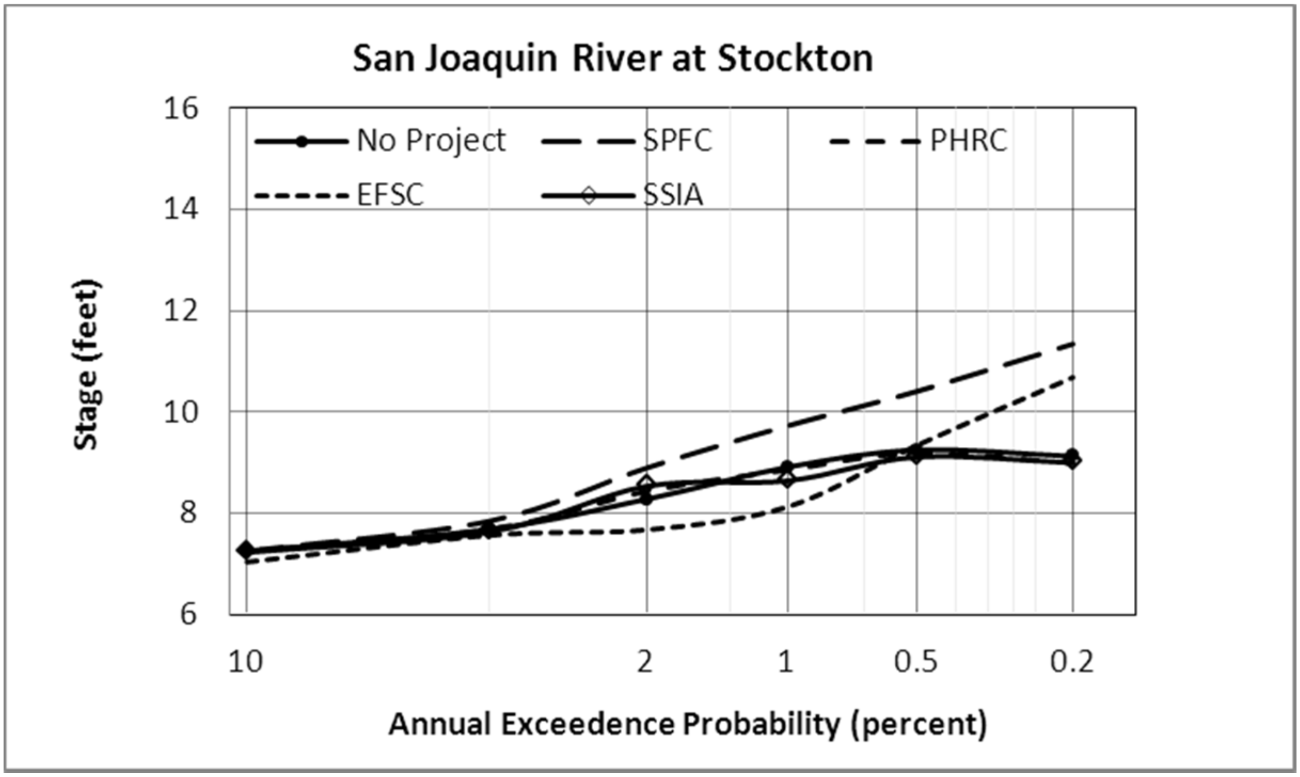


Figure 4-14. Stage-Frequency Curves: San Joaquin River at Stockton [13]

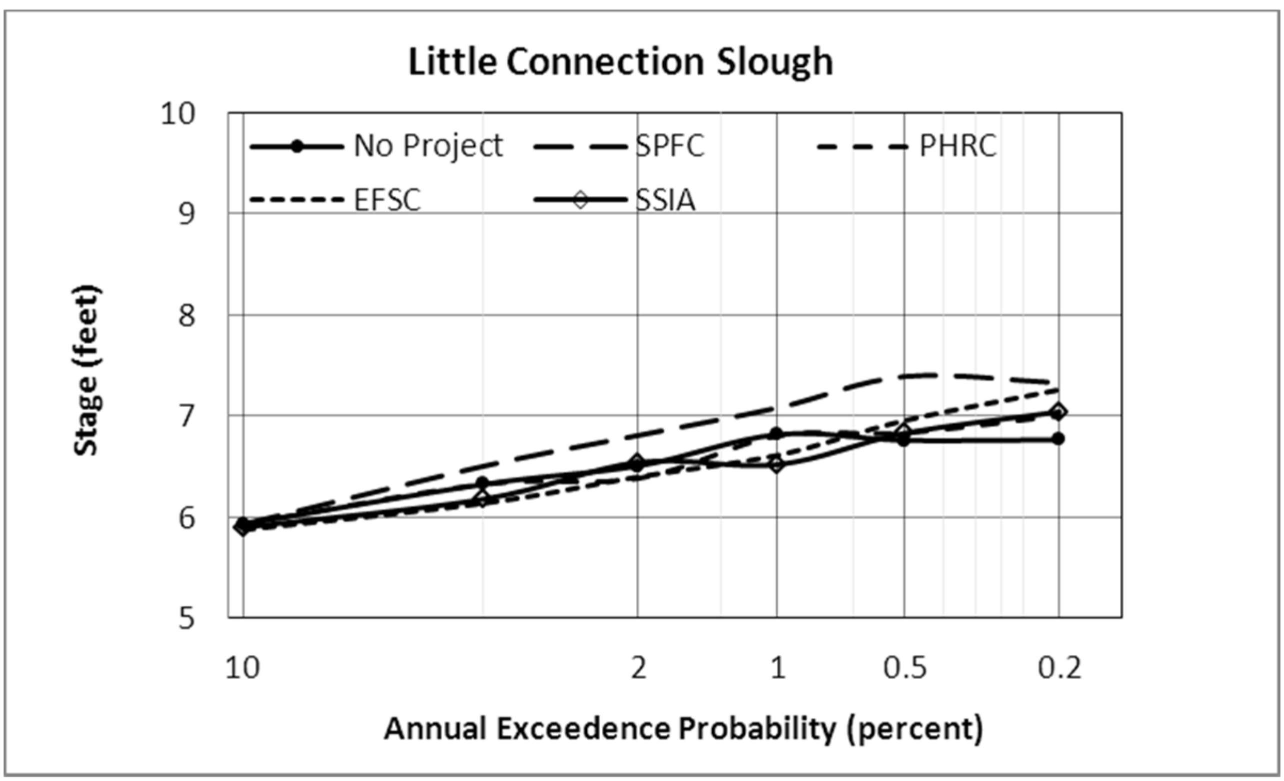


Figure 4-15. Stage-Frequency Curves: Little Connection Slough [14]

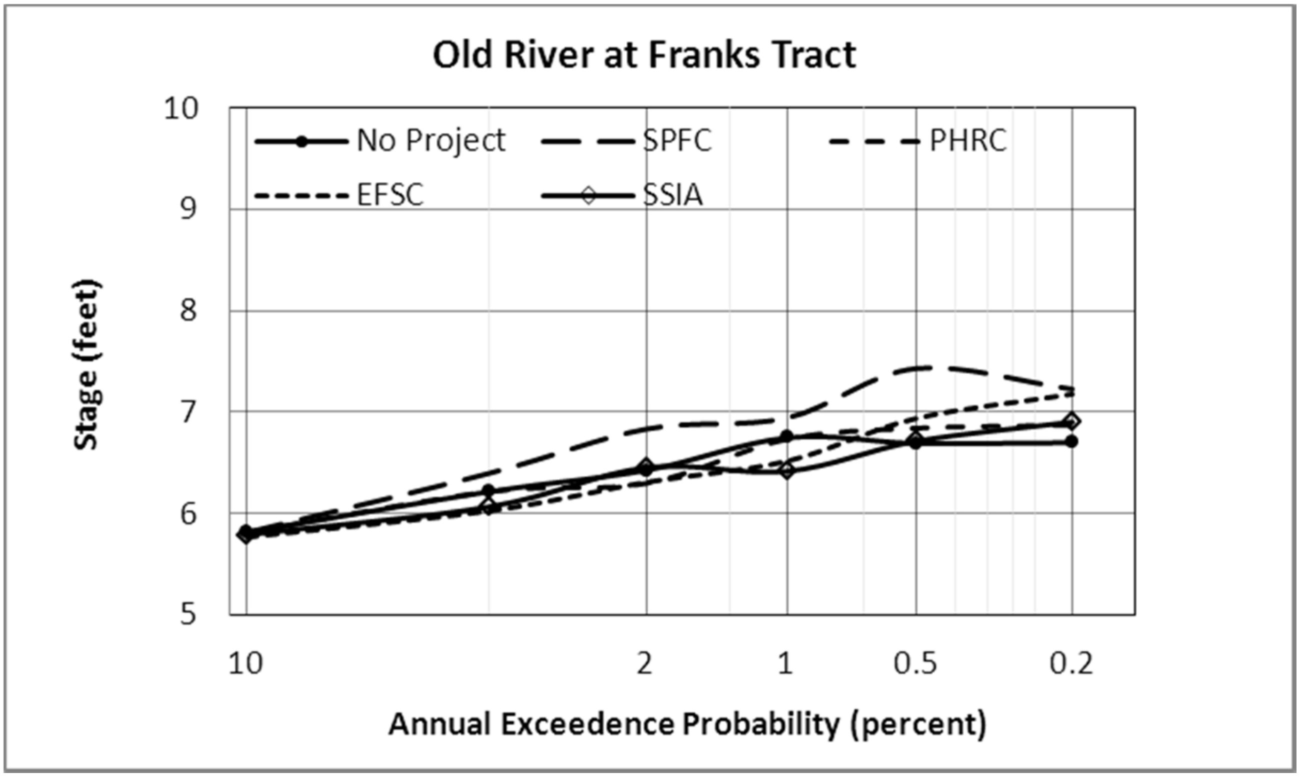


Figure 4-16. Stage-Frequency Curves: Old River at Franks Tract [15]

Table 4-1. Island Inundated (Out-of-System) Volume by Annual Exceedence Probability – No Project Condition

Island Name	Island Inundated Volume due to Flooding (TAF)					
	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Merritt Island					82	91
Pierson District (Courtland/RD551)						211
Sutter Island					38	39
Grand Island					310	307
Tyler Island			148	157	168	179
Brannan-Andrus Island						111
Ryer Island						203
Hastings Tract				75	76	72
Lindsey Slough			70	76	77	78
Prospect Island	4	16	16	17	18	18
Little Egbert Tract		45	46	49	51	51
New Hope Tract						
Staten Island						186
Terminous Tract						
Bradford Island				38	38	38
Webb Tract						
Empire Tract				81	80	81
Stewart Tract					22	32
Roberts Island, Drexler Tract, Jones Tract					422	699
Union Island						119
SE Union Island					5	7
Coney Island					15	17
Mandeville Island						
Venice Island						
Medford Island						
Shima Tract						
Veale Tract						
Victoria Island						
Locke						
Total Volume	**4**	**61**	**281**	**492**	**1,401**	**2,539**

Key:
AEP = annual exceedence probability
RD = Reclamation District
SE= Southeast
TAF = thousand acre-feet

Table 4-2. Island Inundated (Out-of-System) Volume by Annual Exceedence Probability – Restore SPFC Design Flow Capacity Approach

Island Name	Island Inundated Volume due to Flooding (TAF)					
	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Merritt Island						101
Pierson District (Courtland/RD551)						230
Sutter Island						
Grand Island						
Tyler Island			150	157	166	179
Brannan-Andrus Island					111	162
Ryer Island						
Hastings Tract					92	94
Lindsey Slough						
Prospect Island	4	17	19	20	22	23
Little Egbert Tract		48	53	55	60	61
New Hope Tract						
Staten Island						192
Terminous Tract				162	166	167
Bradford Island			38	39	40	39
Webb Tract			-	125	129	127
Empire Tract			80	82	83	83
Stewart Tract						
Roberts Island, Drexler Tract, Jones Tract						660
Union Island						
SE Union Island						9
Coney Island				15	17	18
Mandeville Island					120	120
Venice Island					70	71
Medford Island					10	21
Shima Tract					17	18
Veale Tract					17	
Victoria Island						133
Locke						3
Total Volume	**4**	**65**	**339**	**655**	**1,120**	**2,511**
Change in Volume from No Project	**0**	**5**	**58**	**163**	**-281**	**-28**

Key:
AEP = annual exceedence probability
RD = Reclamation District
SE= Southeast
TAF = thousand acre-feet

Table 4-3. Island Inundated (Out-of-System) Volume by Annual Exceedence Probability – Protect High Risk Communities Approach

Island Name	Island Inundated Volume due to Flooding (TAF)					
	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Merritt Island					85	90
Pierson District (Courtland/RD551)					196	213
Sutter Island					39	39
Grand Island					291	318
Tyler Island			148	157	162	179
Brannan-Andrus Island						119
Ryer Island					193	215
Hastings Tract				75	79	76
Lindsey Slough			72	76	79	78
Prospect Island	4	16	16	17	18	19
Little Egbert Tract		45	46	49	51	51
New Hope Tract						
Staten Island						187
Terminous Tract						
Bradford Island				38	37	39
Webb Tract						
Empire Tract				80	80	82
Stewart Tract					22	32
Roberts Island, Drexler Tract, Jones Tract					421	693
Union Island						119
SE Union Island					5	7
Coney Island						17
Mandeville Island						
Venice Island						
Medford Island						
Shima Tract						
Veale Tract						
Victoria Island						
Locke						
Total Volume	**4**	**61**	**282**	**492**	**1,758**	**2,572**
Change in Volume from No Project	**0**	**0**	**1**	**0**	**357**	**33**

Key:
AEP = annual exceedence probability
RD = Reclamation District
SE= Southeast
TAF = thousand acre-feet

Table 4-4. Island Inundated (Out-of-System) Volume by Annual Exceedence Probability – Enhance Flood System Capacity Approach

Island Name	Island Inundated Volume due to Flooding (TAF)					
	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Merritt Island						96
Pierson District (Courtland/RD551)						
Sutter Island						
Grand Island						
Tyler Island			147	154	167	126
Brannan-Andrus Island						130
Ryer Island						
Hastings Tract						94
Lindsey Slough						
Prospect Island	2	15	16	17	21	23
Little Egbert Tract		43	46	48	56	62
New Hope Tract						
Staten Island						191
Terminous Tract						167
Bradford Island					38	39
Webb Tract					125	127
Empire Tract					81	82
Stewart Tract						
Roberts Island, Drexler Tract, Jones Tract	32	71	71	84	114	176
Union Island					87	164
SE Union Island						
Coney Island					15	17
Mandeville Island						
Venice Island						
Medford Island						
Shima Tract						17
Veale Tract						
Victoria Island						
Locke						
Total Volume	**34**	**128**	**280**	**302**	**705**	**1514**
Change in Volume from No Project	**30**	**68**	**-2**	**-190**	**-696**	**-1,025**

Key:
AEP = annual exceedence probability
RD = Reclamation District
SE= Southeast
TAF = thousand acre-feet

Table 4-5. Island Inundated (Out-of-System) Volume by Annual Exceedence Probability – State Systemwide Investment Approach

Island Name	Island Inundated Volume due to Flooding (TAF)					
	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
Merritt Island					81	87
Pierson District (Courtland/RD551)						146
Sutter Island					38	40
Grand Island						311
Tyler Island			148	154	173	179
Brannan-Andrus Island						
Ryer Island						228
Hastings Tract					74	83
Lindsey Slough				71	76	82
Prospect Island	2	15	16	16	17	19
Little Egbert Tract		42	46	47	49	53
New Hope Tract						
Staten Island						193
Terminous Tract						152
Bradford Island					38	39
Webb Tract						
Empire Tract					81	82
Stewart Tract					21	30
Roberts Island, Drexler Tract, Jones Tract					419	693
Union Island						120
SE Union Island					5	7
Coney Island					15	17
Mandeville Island						
Venice Island						
Medford Island						
Shima Tract						
Veale Tract						
Victoria Island						
Locke				`		
Total Volume	**2**	**57**	**210**	**288**	**1,087**	**2,559**
Change in Volume from No Project	**-2**	**-4**	**-72**	**-204**	**-314**	**20**

Key:
AEP = annual exceedence probability
RD = Reclamation District
SE= Southeast
TAF = thousand acre-feet

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6.0 Acronyms and Abbreviations

1-D	one-dimensional
2-D	two-dimensional
AEP	annual exceedence probability
AF	acre-foot
Bay Area	San Francisco Bay Area
Board	Central Valley Flood Protection Board
Comprehensive Study	Sacramento and San Joaquin River Basins Comprehensive Study
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
Delta	Sacramento-San Joaquin Delta
DICU	Delta Island Consumptive Use
DSM2	Delta Simulation Model II
DWR	California Department of Water Resources
HEC-RAS	Hydrologic Engineering Centers River Analysis System
LiDAR	Light Detection and Ranging
LSJR	Lower San Joaquin River
MAF	million acre-feet
MBK	MBK Engineers
msl	mean sea level
RMA	Resources Management Associates, Inc.
S-F	stage-frequency
SPFC	State Plan of Flood Control
SSIA	State Systemwide Investment Approach
SWP	State Water Project
TAF	thousand acre-feet
TOL	top of levee
UNET	Unsteady flow Through a Full NETwork of open channels computer model

UPRR..............................Union Pacific Railroad

USACE ............................U.S. Army Corps of Engineers

USGS ..............................U.S. Geological Survey

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES